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ESSENTIALS *of* NUTRITION

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NEW YORK
THE MACMILLAN COMPANY

PUBLISHED SEPTEMBER, 1940
Third Printing, October, 1941.

PRINTED IN THE UNITED STATES OF AMERICA
AMERICAN BOOK—STRATFORD PRESS, INC., NEW YORK

PREFACE

THE purpose of this book is to offer its readers a thoroughly adequate and up-to-date view of the essentials of nutrition.

We hope that it will be found useful both to those who do and those who do not expect to proceed later to a more detailed, professional study of nutrition and dietetics.

Special care has been given to the mode of dealing with such terms as nutrition uses in common with other sciences, and such as are just now in course of becoming everyday words. Recognizing that the effectiveness of the text depends largely upon freedom from interruption by formal definitions, we have sought rather to introduce each scientific term only as its employment becomes clearly useful, and then functionally. For cases in which more dictionary-like definitions may also be useful a glossary is provided in Appendix G.

It is realized that at present the teaching of nutrition, like the scientific subject matter itself, is in a rapidly developing stage. It is hoped that this text will contribute to this development, and that its use will enable the teacher more readily to meet the demands of the growth of fundamental scientific knowledge of nutrition within the time-limits of the non-technical course.

The present approach to the facts and principles of the science of nutrition is mainly through the relations of food to health and efficiency. Chief prominence is given to the case of the normal young person such as the majority of the

readers of this book will presumably be; though the concluding chapters take up also the problems of food for family groups, and of making nutritional knowledge more widely effective. Most of the Exercises at the ends of the chapters are, like the text itself, put in terms of the student's own experience and objectives. The Exercises and Suggested Readings are to be regarded as entirely optional. In many courses, no doubt, actual laboratory work will be provided instead. One of our main objects is to provide a textbook which leaves the teacher entirely free to design the accompanying laboratory work, or collateral reading, or both, in accordance with the circumstances and purposes of the particular course. The sequence of topics is also readily adjustable.

The subject matter of the text begins with an introductory chapter which is intended to indicate both the position of the present-day science of nutrition and its constructive aims. For many, such an advance indication of the far-reaching significance of our newest knowledge of nutrition increases the interest and effectiveness of the study. Those, however, who prefer to omit or postpone such evaluation will find it entirely feasible to make a logical beginning with the second or even with the third or fourth chapter.

Then follows the central body of the topical subject matter, treated in the order which most teachers prefer: (1) the energy aspects of nutrition, (2) the proteins and their amino acids, (3) the mineral elements, and (4) the vitamins.

This is generally found the most satisfactorily teachable sequence from the viewpoint of the interrelationships of the topics. It has also another important advantage. To a noteworthy extent it corresponds with the chronological sequence in which the main aspects of the present-day science of nutrition have developed. Thus we study first the parts of our subject which have had longest in which to take definite shape and which can therefore be presented most simply and concisely. After this we are better prepared for the somewhat more detailed treatment which the newer subject matter of

the vitamins requires if its study is to be of equal scientific soundness. Some of the most recent advances of knowledge in the vitamin field are so important, in the light which they throw upon everyday nutritional problems, that the somewhat fuller mode of exposition here finds a practical reward as well as a teaching reason.

The chapters on vitamins are so written that they may be studied in any sequence desired. The order followed in this text is the one which to us seems, in the present state of knowledge, best adapted to effective teaching. As a further aid to interest, the arrangement within each chapter is determined by the merits of its own subject matter in preference to the rigid following of a fixed form. If desired, chapters XIV and XVII may be omitted without loss to the understanding of the other chapters.

The last four chapters are extensions of nutrition study into broader fields. Any of them can be omitted, without impairing the scientific coherence of the body of the book, when adaptation to a shorter course is desired or the teacher prefers to develop some other line of application.

The tables in the body of the text are kept short for comfortable reading. Data of food values thus used, to illustrate or to amplify some particular chapter, are taken as typical from among the much more numerous data tabulated in the Appendix. These tabulations, and particularly the quantitative data for vitamin values of foods, represent the results of a very extended and painstaking study of all the evidence available to the authors up to the end of February 1940.

For the privilege of using unpublished data in drawing our deductions, for the use of illustrative materials, and for guidance in other ways, we are indebted to many scientific friends among whom certainly specific acknowledgment is due to Drs. E. L. Batchelder, F. G. Benedict, L. E. Booher, C. A. Browne, H. L. Campbell, T. M. Carpenter, E. F. DuBois, Martha Eliot, C. J. Farmer, E. C. Kendall, C. G. King, H. E. Munsell, John B. Nichols, and M. S. Rose.

CONTENTS

ESSENTIALS *of* NUTRITION

Chapter I

THE NUTRITIONAL IMPROVEMENT OF LIFE

Students now enter American colleges taller and yet younger than were their parents and other predecessors when they entered the same colleges thirty years ago. This is shown consistently by all the available records, and is true of both boys and girls. There has not been any known change in proportions of racial stocks which could account for the differences. The explanation is to be found not in inheritance in the biological sense but in a social inheritance,—the increase of scientific knowledge and its use in the betterment of conditions of living.

Prominent among the advances in knowledge of life and health and resulting improvement of ways of living has been the development of the science of nutrition and its influence upon the daily choice and use of food.

A generation ago, all the more abundant constituents of food were sufficiently known to chemists so that one might analyze a food with as much accuracy as a rock or a soil, yet one could not successfully nourish himself or an experimental animal with a mixture of the food constituents which analysis revealed.

Professor (now Sir) Frederick Gowland Hopkins of Cambridge University reported briefly in 1906 and fully in 1912 his experiments which made clear to students of normal nutrition that there must exist in certain foods some substance or substances not previously known, but essential to the nutritional process. He showed that laboratory animals soon ceased to thrive on mixtures of purified proteins, fats,

carbohydrates, and salts even when these were selected and proportioned in the light of all available knowledge; but that the addition of a small amount of milk, fresh or dried, or of the alcohol-extract of dried milk or of certain vegetables (but not the ashes of such foods or extracts) made the diet adequate. Figures 1 and 2 show graphically the results of typical experiments. Those experiments showed that some unidentified alcohol-soluble organic substance or substances must function in normal nutrition. We now know that there are several such substances, some soluble in water and others in fat. Individually, they will be studied in Chapters XI-XVII. In the present discussion we are concerned with the general relation of this discovery and its sequel to the significance of nutrition as a factor in our understanding of nature and in the scientific management of our own lives.

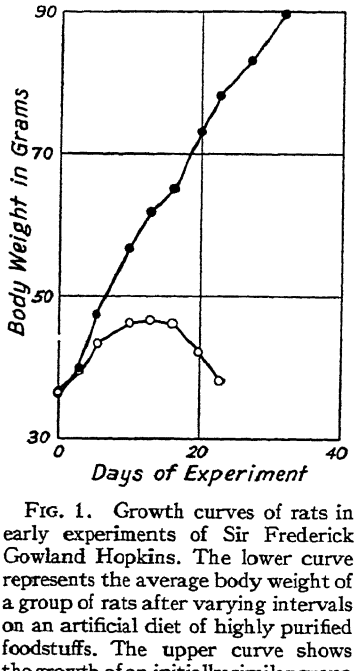

FIG. 1. Growth curves of rats in early experiments of Sir Frederick Gowland Hopkins. The lower curve represents the average body weight of a group of rats after varying intervals on an artificial diet of highly purified foodstuffs. The upper curve shows the growth of an initially similar group of rats receiving 2 cc. of milk each per day in addition to the artificial diet. (*Courtesy of Sir F. Gowland Hopkins.*)

For the discovery of these substances,—tentatively called vitamins and beginning to be known by more distinctive individual names,—has proven to be only the first step in a very far-reaching scientific development of great importance to the improvement of life.

Modern science constantly strives to make itself more and more exact. So as soon as the existence of "vitamins" was discovered, even without waiting for their complete chemical identification, studies were begun upon such quantitative questions as: (1) the relative abundance of a given vitamin

in different kinds of food; (2) the amounts needed in nutrition; and (3) the more ambitious question, how much of each gives the *best* results, *i.e.*, what is the level of *optimal* as distinguished from merely adequate *nutritional intake*.

Our present-day realization of the importance of this latter problem is a development of much greater significance than is yet generally understood.

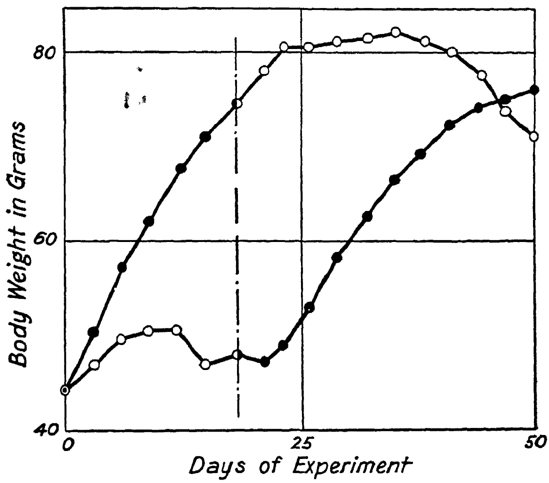

FIG. 2. Growth curves of rats in early experiments of Sir Frederick Gowland Hopkins. The lower curve represents the growth of rats receiving (up to the 18th day of the experiment) only the purified diet; the upper curve, similar rats having (up to the 18th day) 3 cc. of milk each per day in addition to this food. From the 18th day of the experiment, marked by the vertical dotted line, the milk was transferred from the latter set of animals to the former. (*Courtesy of Sir F. Gowland Hopkins.*)

While this fact was revealed largely through experiments which grew out of the investigation of the newly-discovered vitamins, it is equally true of some of the mineral elements which have long been recognized as essential to nutrition but whose far-reaching potentialities have but recently been brought fully to light. (For example, the work with different levels of calcium intake, noted in Chapter VIII.)

The rapid sequence of such discoveries has been in great

measure due to the increasing use of laboratory animals as instruments and reagents of nutritional research. By use of a species whose nutritional chemistry is closely similar to ours and which runs much more rapidly than we do through its growth and development and the subsequent events of its life history, science can now study the relations between food intake, nutritional responses, and resulting health, much more comprehensively than had previously been possible.

For about twenty years McCollum has taught that there may be important differences between the merely adequate and the optimal in nutrition. And J. F. Williams, in his teaching of personal hygiene, has emphasized that health may and should mean not merely freedom from disease but rather a positive quality of life, and that there are degrees of this positive health; though even recently he remarked that this view had not yet found wide acceptance. That acceptance of this view of health is now rapidly spreading, or, as the *Journal of the American Medical Association* has editorially phrased it, "that the difference between buoyant health and merely passable health is coming to be more appreciated," is doubtless largely due to the objective and quantitative nature of present-day nutritional research. For this gives to its findings an impersonal convincingness which advances the principle of the nutritional improvability of the normal out of the realm of opinion into that of established physiological fact. Such nutritional improvement of already-normal health has been shown at every stage of the life cycle with statistical convincingness and conclusiveness of a very much higher order than science considers necessary to establish a physiological fact as "undoubted."

Thus notwithstanding individual (physiological) variability, the well-controlled colony of experimental animals, from which large numbers of strictly comparable individuals of known hereditary and nutritional antecedents can be drawn, becomes an instrument of research such as has never existed before. By the use of this instrument, higher precision and deeper insight both become possible; and these in turn are

revealing an essentially new concept of the influence of nutrition.

To make this clear and definite, let us glance at some recent and current work at Columbia University where there is maintained for research of this kind a colony of laboratory-bred experimental rats in which the hereditary and nutritional background of each individual is known for so many generations as to correspond with a human population whose food supply had been known, whose blood had been unmixed, and whose family trees could be traced in all their branches, for well over 1000 years. With such a colony to draw upon, strictly parallel test groups can be placed simultaneously upon the different dietaries which it is desired to compare.

In all such controlled research, we plan to introduce only one variable at a time. In nutritional problems of the sort which we are considering, the experimental variables are of two kinds: (1) individual chemical factors, elements or compounds as the case may be; and (2) the actual articles of food which nature and agriculture produce and which people obtain and consume.

In a case of the latter type, a certain basal *Diet A* showed itself adequate under the severe test of maintaining fully normal health with successful reproduction and rearing of young, generation after generation; yet when the proportion of milk in this food supply was doubled the resulting *Diet B* was better in that it induced a more buoyant health, or built the already-normal health to a higher level.

Whether at this higher level the actual optimum has been reached, or whether that is higher still, remains to be determined; but the measured differences in well-being, between the adequately nourished families on Diet A and their cousins who received the still more scientifically balanced Diet B, show clearly and conclusively that our knowledge of nutrition is now entering a new era in which it can (and doubtless will) play a larger part in the attainment of a higher general level of health and efficiency than has hitherto been thought possible.

In the investigation just mentioned, the only experimental variable was the proportion in which the natural foods entered into the diet; but the increased proportion of milk when translated into chemical terms meant major enrichments of the diet in the three chemical factors calcium, vitamin A, and riboflavin which we shall study individually in Chapters VIII, XIII, and XV. New series of experiments were therefore begun with calcium, vitamin A, and riboflavin, respectively, each studied independently and at successively increased levels of intake.

Here it is being found that calcium, vitamin A, and riboflavin each is capable of conferring successively increased benefit at successively higher levels of intake through an unexpectedly wide range. Hitherto, it has been the accepted view (sometimes even expounded as a fundamental economic principle) that one cannot advantageously consume much more food than one actually needs; in other words that, in the case of food, the level of minimal adequacy is very nearly the optimal level of consumption. This now proves to have been an oversimplified view. A more discriminating statement is needed. Of total food as measured in calories a very small surplus above actual need *does* suffice to bring us to the optimal level of intake of *this* nutritional factor. And probably of many other factors the optimal level is only moderately higher than that of minimal adequacy, perhaps around fifty per cent higher as is commonly assumed for protein and for phosphorus in the teaching of dietetics. But for *some* factors we now find that the beneficial margins are much higher than this.

This finding, with its consequences which we shall later study more fully, has such far-reaching significance that some have inclined to call it "a new principle of liberality in dietetics"; but it should not be confused with a merely openhanded attitude. The *principle* is one of *scientific discrimination*. What is true of calcium is *not* to be assumed to be true of other mineral elements; and what is true of vitamin A and riboflavin is not to be assumed to be true for other

vitamins. These three factors were not taken at random for the investigation above mentioned. They were investigated because the results of a previous investigation pointed directly and specifically to them as probable keys to the fuller understanding of a newly discovered nutritional improvability of an already-normal condition or level of health.

Undoubtedly, hitherto, if we have appreciated the reality of degrees of positive health, we have been too fatalistic in our attitude toward it, attributing the superior vitality which some people enjoy too largely to their luck in being born with good constitutions and too little to their intelligent habits of life.

Lately, it is becoming increasingly clear that, however important the inherited constitution, there is yet a very great opportunity open to each of us to provide through sane daily living, and notably through intelligent food habits, for such a favorable internal environment* as shall permit our native endowments to develop and function to the best advantage.

Hopkins, speaking in the most conservative terms as President of the Royal Society, has recently said that "nurture can assist nature to a larger extent" than the passing generation has thought.

That differences which are really nutritional have doubtless sometimes been attributed to racial factors was emphasized by Hopkins in the leading article of the then newly established *Nutrition Abstracts and Reviews* in 1931. A community, he explains, may be found in equilibrium with an environment which includes its food supply, and the fact of such equilibrium has hitherto been taken as evidence that the environment supplies everything needed. Hence any inferiority was taken to be racial, whereas actually a racial potentiality of higher development may become manifest with an improvement in the food.

This is illustrated in the fact, repeatedly emphasized by Boas, that in immigrant families supposedly representing

*See Glossary (Appendix G).

physically inferior racial stocks the children and grandchildren approach the typical American physique with surprising rapidity when living under American conditions.

And that physique is only the most obvious and not necessarily the most important of the gains to be expected is illustrated by Dr. McLester's statement in an official address as President of the American Medical Association: that science now offers, to those who will use the newer knowledge of nutrition, greater vigor "and a higher level of cultural attainment."

Thus we are now in a new era of nutritional knowledge, in which this knowledge serves the improvement of life in two ways: (1) correctively, in the cure and prevention of deficiency diseases and of the less well recognized states of nutritional shortage or subnormality; and (2) constructively, in the improvement of already-normal health.

We can now see that the teaching of science has until recently assumed the normal internal chemistry of each species to be somewhat more rigidly specific than it really is. The newer knowledge of nutrition shows us, among other things, how our daily choice of food influences that internal environment of the body which directly environs and conditions the life process. And the new knowledge has brought a really new view.

For hitherto, while we included nutrition among environmental factors by definition, yet when we actually thought about environment it was chiefly to think about our surroundings. As we come to realize how significantly our daily choice and use of food influences that more important environment which we carry within our own bodies, we see that we ourselves have a much larger measure of ability to improve the life process than science has hitherto thought.

The chapters which follow will seek to make clear the essentials both of the facts of our present-day nutritional knowledge and of the functioning of this knowledge in the guidance of daily food habits and the attainment of higher health.

EXERCISES

1. Record your present height, weight, and age (dating and signing the record). Note also the age, and (if you know them correctly) the height and weight at which you entered college. How do your height and weight compare with the normal average or standard for your age? Is your build average or slender (linear), or stocky (lateral)?

2. Make an accurate record of the kinds of food and beverage and the amount of each which you consume (*a*) in a 24-hour day; (*b*) in each of 7 consecutive days.

3. Check the foregoing record against the accompanying U. S. Department of Agriculture Card, or such other guide as may be selected. The writers have here chosen, for reasons more fully explained beyond, a card designed primarily for young people.

Checking Card of
UNITED STATES DEPARTMENT OF AGRICULTURE
EXTENSION SERVICE
DIVISION OF COOPERATIVE EXTENSION
(Adapted)

Check Your Meals Daily for These Foods:

Milk	1½ pints to 1 quart
Butter	1 to 3 servings
Fruits and vegetables (interchangeable to some extent)	4 to 5 servings
A good balance is:	
1 serving potato	
1 serving citrus fruit, tomatoes, or raw cabbage	
1 serving green or yellow vegetable	
2 additional servings—fruits or vegetables (emphasize green and yellow kinds)	
Whole-grain bread or cereals	1 to 2 servings
Eggs, meat, fish, cheese, dried beans, or peas (select two different kinds)	2 servings
Total liquids (water, milk, soup, fruit juices and other beverages)	2 quarts or more

---

Cod-liver oil (a fine supplement in winter or when you cannot afford plenty of whole milk, butter, eggs, and green-colored vegetables)	1 teaspoon

With the above, use additional bread and cereals and moderate amounts of sweets and fats to make up sufficient food energy (total calories).

(Remember that the somewhat conventional use of any such "score card" would lose much of its convenience if it were subject to frequent change; and that, therefore, it can not be expected to reflect precisely the most up-to-date knowledge, and its implied judgments need not be regarded as final. Perhaps you may find reason to modify some of them as a result of your study of nutrition. Nevertheless its use may be helpful to thinking and discussion.)

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Chapter II

THE MORE ABUNDANT NUTRIENTS IN FOODS

The food as a whole *nourishes* the body in three ways:

(1) it supplies the body-fuels, the substances whose burning (oxidation) in the body supplies the *energy* for its activities;

(2) it provides the materials for the *building* and *upkeep* of the body tissues; and

(3) it furnishes the substances by means of which the conditions and processes in the body are *regulated*, or the *precursors* from which the body makes its regulatory substances.

A *nutrient* is a substance which takes part in a nutritive function of any of these three kinds. Some nutrients function in more than one of these ways. Strictly speaking, air and water are nutrients*; but more commonly the body's supplies of air and water are treated rather as parts of the study of physiology and hygiene, while the study of nutrition takes them for granted and concentrates its attention upon the food supply and the fate and functions of the foodstuffs (nutrients) in the body.

An individual food may serve one, or two, or all, of the three types of function above mentioned according to the nutrient or nutrients which it contains.

This brief indication of functions will probably serve better to introduce the study of the nutrients, than would a set of formal definitions. It may, perhaps, be worth while to note at this point that the literature of nutrition uses the term

*Some of the early observations upon the essential function of air and the significance of respiration as related to nutrition are interestingly described in pages 3 to 13 of *Foundations of Nutrition*, Third Edition, by M. S. Rose.

"foodstuffs" in two senses. Some writers follow popular usage in making no distinction between "foodstuffs" and "foods," meaning in both cases articles of food, or food commodities. Others use foodstuffs rather as a scientific term to mean the "stuffs" in the sense of the constituent substances of which foods are composed. When used in this latter sense, the word foodstuff becomes practically interchangeable with the word nutrient.

Because of their many important interrelations, the nutrients cannot be rigidly classified according to which of the three main types of nutritive function they serve. This will become clearer as subsequent chapters are studied. The present chapter relates chiefly to the nutrients which bulk largest in the food as a whole.

As we saw in the preceding chapter, the vitamins which play such a prominent part in recent discussions of food and nutrition are concerned in such very small amounts as for a long time to have been missed in the quantitative accounting for the composition of foods. The longer-known constituents of foods are proteins, fats, carbohydrates, organic acids, inorganic salts or mineral elements, and water.

Typical examples of these constituents of foods may be illustrated in observations readily made upon milk, the one thing whose sole function in nature is to serve as food. As one receives a bottle of milk from the dealer, a partial separation of its constituents is usually already visible in the presence of a cream layer, due to the fact that the globules of *fat* which the milk contains, being lighter than the watery medium in which they float, are rising to the top. The fat of the milk may be removed by skimming-off the cream, or more quickly by means of a centrifugal separator, leaving the skimmed milk. Either whole or skimmed milk when treated with rennet or when simply allowed to sour *curdles*, the curd being due essentially to casein, the characteristic *protein* of milk. (This and other proteins will be studied briefly later in this chapter, and more fully in Chapter VI.)

When the fat and the curd have been removed from milk the remaining whey if concentrated and allowed to stand yields crystals of *milk sugar*, which belongs, like the other sugars and the starches, to the group of substances called *carbohydrates*.

If whey residue, or if the original milk, be dried and burned there remains a mixture of *mineral* matters,—the *ash*. In addition to water and (other*) mineral matters, protein, fat, and carbohydrate, milk contains citric acid, typical of the *organic acids* and most readily recognized in the citrus fruits; and soured milk contains lactic acid, the most familiar of those organic acids whose presence in foods is chiefly due to fermentation of one kind or another.

The *vitamins*, while of great importance to the nutritive value of the diet, constitute as we have seen such an elusively small fraction of the weight of any food that they are usually treated separately from the general discussions of the foodstuffs. Often, too, all minor constituents are either ignored or counted with the proteins, fats, or carbohyrates, whichever they most resemble.

In what follows in this chapter we consider these three groups in the order carbohydrates, fats, and proteins as being, on the whole, the most logical progression from the simpler to the more complex.

CARBOHYDRATES

Sugars and starches, with a few related substances, are grouped under the name carbohydrates. This group name was suggested by the fact that these substances are composed of carbon, hydrogen, and oxygen, and that the hydrogen and oxygen are here in the same quantitative relation to each other as in water. Of special interest to the student of nutrition are the relationships between members of the three subdivisions of the carbohydrates as illustrated in the sections which follow.

*The science of mineralogy claims water as a mineral.

Monosaccharides

The simplest of the carbohydrates, and the ultimate carbohydrate-units into which the more complex carbohydrates can be broken (as by digestion) are called monosaccharides. The significance of "mono" in the name is to emphasize their simplicity or "single-sugar-ness" of chemical nature (as contrasted with the disaccharides and polysaccharides to be mentioned below). Glucose, fructose, and galactose are the three monosaccharides of most importance in nutrition.

Glucose (also called dextrose, grape sugar, corn sugar, starch sugar) is widely distributed in nature, occurring in small amounts in the blood of all animals, and much more abundantly in many fruits and plant juices. It is especially abundant in grapes, of which it often constitutes 20 per cent of the total weight or more than half of the solid matter. Sweet corn, onions, and unripe potatoes are among the common vegetables containing considerable amounts of glucose. Pure dextrose made from cornstarch is now largely marketed as corn sugar; and it has been announced that so far as practicable corn sugar and cane sugar will receive equal treatment in the administration of the Federal Food Law.

Fructose (levulose, fruit sugar) occurs with glucose in plant juices, in fruits, and especially in honey, where it makes up about one-half of the solid matter. It is formed, along with an equal weight of glucose, when ordinary cane or beet sugar is digested.

Galactose is important because it is formed, along with an equal weight of glucose, when milk sugar is digested.

Disaccharides

The name *disaccharide* implies a substance each molecule of which can be broken down into two monosaccharide (simple sugar) molecules. The three nutritionally important members of this group of carbohydrates are sucrose (cane or beet sugar), lactose (milk sugar), and maltose (malt sugar).

Sucrose (saccharose, cane sugar), which upon digestion gives one molecule of glucose and one of fructose, is present in considerable quantity in the fruits and juices of many plants. The commercial sources of sucrose are the sugar beet, the sugar and sorghum canes, the sugar palm, and the sugar maple; but many of the common fruits and vegetables contain notable amounts. For example, sucrose is said to constitute at least half the solid matter of pineapples and of some roots, such as carrots.

The per capita consumption of the practically pure cane sugar of commerce increased rapidly for a century in the United States (Fig. 3) until now it is estimated that on the

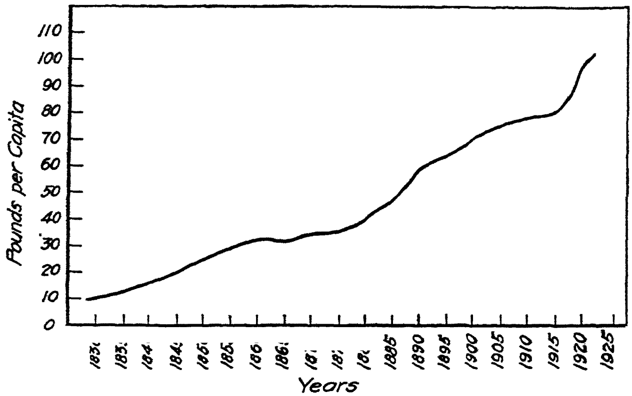


FIG. 3. Trend of the annual per capita consumption of refined sugar in the United States from 1825 to 1925.

average about one-seventh of our food calories are derived from this source. The question whether it is wise to take so much of a food which contributes none of the nutritionally important protein, mineral elements, and vitamins, may more profitably be discussed after the study of Chapters VI to XV.

Lactose (milk sugar) occurs in the milk of all mammals, usually constituting 6 to 7 per cent of human milk and 4.5 to 5 per cent of cows' and goats' milk. When digested it yields glucose and galactose in equal proportions.

Because lactose is regarded by some physicians and bac-

teriologists as markedly beneficial in maintaining a desirable state of the lower intestinal tract, many persons make a special effort to secure a liberal intake of this sugar, either through generous use of milk or by addition to their diet of pure lactose. As yet, the consumption of lactose in this country is far less than the amount which its dairy industry could very readily supply. The sweeter, more soluble form of this sugar is known as beta-lactose.

Maltose (malt sugar) occurs in germinating cereals, malt, and malt products. It also appears as an intermediate product when starch is digested in the body. Maltose, whether eaten as such or formed in the course of digestion, is not absorbed to any important extent, but is further broken down in the digestive tract, each molecule of maltose yielding two molecules of glucose.

Polysaccharides

Complex carbohydrates, each molecule of which represents many molecules of monosaccharide, are called *polysaccharides*. Starch, the dextrins, glycogen ("animal starch"), cellulose, and the hemicelluloses, are the only members of this group which need be mentioned here.

Starch (whose ultimate digestion-product is glucose) is the form in which plants store the largest part of their reserve carbohydrate material, and is of great importance as a constituent of many natural foods. It occurs in the seeds, roots, tubers, bulbs, and to some extent in the stems and leaves of plants. It constitutes one-half to three-fourths of the solid matter of the ordinary cereal grains and at least three-fourths of the solids of mature potatoes. Unripe apples and bananas contain much starch which is to a large extent changed into sugars as these fruits ripen; while, on the other hand, young tender corn (maize) kernels and peas contain sugar which is transformed into starch as these seeds mature.

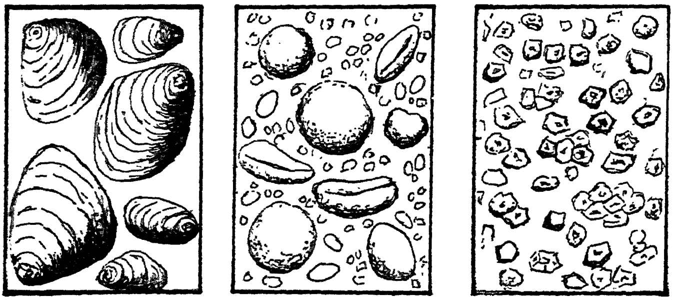
Starch granules of some typical plants are shown in Fig. 4.

Each molecule of starch contains many glucose units. Starches contain in addition a minute proportion of non-

carbohydrate acid radicles, sometimes of fatty acid and sometimes containing phosphorus.

Starch granules are insoluble in cold water and apparently little affected by it; on warming, however, they absorb water and swell, passing eventually into a sort of semi-solution, and in this state they are very much more easily digested than is raw starch.

In digestion, the starch of the food is changed into smaller polysaccharides, the *dextrins*, and these into the disaccharide maltose. Since, as already indicated, maltose is further digested into glucose, it is as glucose that the large quantities of carbohydrates eaten in the form of starch become available to the body.



Potato Wheat Corn

FIG. 4. Granules of starches prepared from potatoes, wheat, and corn. In each case, the granules are magnified about 300 diameters.

Glycogen is very similar in chemical composition to starch, and as it plays in some respects much the same rôle in animals which starch plays in plants, it is sometimes called animal starch. It occurs in many parts of the animal body, predominantly in the liver and the muscles.

Cellulose is familiar as a woody or fibrous material occurring in the cell walls of all vegetable tissues. It is a polysaccharide of glucose, more resistant than starch, and is only softened by cooking processes.

The hemicelluloses are polysaccharides which botanically resemble cellulose in belonging to the walls rather than to

the contents of plant cells. Chemically, they are not so well defined as cellulose, and hemicelluloses from various sources have been reported to yield on hydrolysis different monosaccharides or mixtures of monosaccharides.

Undigested cellulose and hemicelluloses give bulk to the intestinal residue, and this has some effect upon its regular movement. It is well to remember that individuals vary as to what constitutes sufficient bulk without too much roughage; and also that not only indigestible matter but fruits or their juices as well may be efficient in promoting intestinal regularity.

FATS AND LIPOIDS

The Nature and Scientific Significance of the Fats

Fats are composed of the same three chemical elements as are the carbohydrates, namely, carbon, hydrogen, and oxygen.

The true fats are chemically *triglycerides*, *i.e.*, the molecule of fat yields on digestion one glycerol and three fatty acid molecules.

The names applied to the individual fats generally indicate their fatty acid composition; as for example, *tristearin*, which contains three stearic acid radicles; *oleo-dipalmitin*, which contains one oleic and two palmitic acid radicles; *stearo-oleo-palmitin*, which has one radicle each of stearic, oleic, and palmitic acids.

The three fatty acids just named are the ones which occur most abundantly in food fats generally. Others are more characteristic of particular fats, *e.g.*, the butyric acid of butter.

A number of the fatty acids are listed with their chemical formulae in the Appendix at the back of this book.

The fatty acids (which make up very much the largest part of the weight of any fat) have higher percentages of carbon and hydrogen and lower percentages of oxygen than do the carbohydrates, so that fats constitute much the more concentrated form of fuel.

Typical fats are not soluble in water but can be dissolved in a "fat solvent" such as ether, "petroleum ether," or chloroform. In the preparation of food fats, however, solvents are rarely used. Butter is, of course, obtained by churning; and most other fats are "rendered" either by pressing the fat out of the tissue, or by melting the fat and removing the residual tissue by settling or straining, or both.

The common commercial food fats have a wide variety of origins: butter from milk; lard, suet, and some margarines from meat fats; corn oil (maize oil) from the embryo of a cereal grain; peanut (arachis) and soybean oil from the seeds of leguminous plants; coconut oil, palm oil, and palm kernel oil from the seeds of palms; cottonseed and sesame oils from the seeds of other plants; olive oil from the flesh of a fruit.

While Italian cookery prefers olive oil as its chief fat, American households tend to follow the English, French, and German tradition of using butter as freely as income allows, with lard or a "lard substitute" as next choice, meaning by lard substitute a fat mixture or preparation of essentially the same plasticity and melting point as lard. Thus cottonseed oil as such finds relatively slight use in the American kitchen; but hydrogenated to the consistency of lard it finds a large sale as a cooking fat.

Liquid fats and those which melt at our body temperature are somewhat more readily and completely digested than those which are much harder.

As butter substitutes, in order to be acceptable to the consuming public, must have about the same consistency and melting point as butter, they are apt to have nearly the same digestibility. For the same reason, there is not apt to be any important difference in digestibility between lard and commercial lard substitutes. Fats in general tend, however, to slow down the digestive process; and the more so the greater the proportion of fat in the food as a whole.

Problems of fat supply, which became acute in the first World War and have continued to receive attention since,

have led to a broadening of attitude of the consuming public toward food fats. Refined cottonseed oil, whether as such or hydrogenated to the consistency of a plastic fat like lard, has come to have a much more unquestioned place in the food supply than formerly; maize oil has grown rapidly in acceptance as a human food; and recently there has been described the preparation from Georgia pecans of a commercially practicable refined edible oil comparable with olive oil.

Certain highly unsaturated fatty acids, such as linoleic and linolenic (or fats containing them), seem to be a nutritionally essential part of the diet. The quantity which the food must furnish evidently need not be large; and thus far the tendency has been to assume that ordinary everyday dietaries will supply this need without our giving it any thought. This attitude may, perhaps, need some modification in view of recent observations connecting this nutritional factor with that known as vitamin B_6, as will be explained in Chapter XIV.

Fat-like and Fat-soluble Substances

Fats are usually accompanied by *lipoids:* fat-like substances soluble either in fat solvents or in the fat itself. Some of these, including the *lecithins*, are closely related to fats in their chemical nature; others, such as the *sterols*, are "fat-like" rather in their physical properties than in their chemical natures. We shall meet the lecithins again among phosphorus compounds, and the sterols in connection with the vitamins D.

Lipins and *lipids* are names sometimes used to cover both the true fats and the lipoids of all kinds.

The choice among fats as food is now largely (and very logically) influenced by the fact that some contain relatively much, and others practically none, of the important fat-soluble vitamin A, consideration of which is here deferred to Chapter XV.

Prominence of Fat in Some Everyday Food Problems

Scientifically it has been shown that fat and carbohydrate are interchangeable as body fuel throughout a very wide range of proportions. In practice, there are certain facts, partly physiological and partly psychological, which tend to make the proportion of fat in the food a prominent factor in practical dietetics.

Fat is not only a food of high fuel value; foods also seem "richer" the more fat they contain, and correspondingly they "stay by" longer. The latter expression means chiefly that, other things being equal, the more fat a given meal contains the longer the time before it will have left the stomach. It is when the stomach is empty that the muscular contractions of its walls give rise to the "pangs" of hunger. Hence among the peoples of the Western World who have become accustomed to a fairly liberal use of fat in their daily food, any shortage of fat is felt both in the difficulty of getting the desired effects in cookery and in the fact that the low-fat meals leave the stomach more quickly so that there is much more sensation of hunger before the next meal. When the physiological effect is further complicated by the anxiety accompanying a period of inadequate and uncertain food supply, the shortage of fat may become a real factor in impairment of morale, as was demonstrated in Europe during the first World War.

Hence the art of dietetics as practiced in America and Europe tends to furnish from one-fourth to one-third of the total food calories in the form of fat. With much less than one-fourth there tends to be dissatisfaction for such reasons as mentioned above, while much more than one-third of the food calories in the form of fat tends to give rise to sensations of excess.

When food is so rich in fat as to stay too long in the stomach, this organ may become fatigued or may even rebel. Here importance may also be attached to the way in which the fat is used in cookery. Fried foods are apt to come under special suspicion (1) that they may have been allowed to absorb too much fat, and (2) that irritating substances may have been formed in the fat by the heating to which it was subjected in the frying pan. Hence the advice to sear quickly the surface of the food which is being fried and then lower the temperature so that the interior "cooks in its own juice." Clearly, too, a surface water-proofing of fat, such as will keep the food juices in, must also

tend to keep the digestive juices out; so that the presence of fat retards the digestion of carbohydrates and proteins, and the more so the more the fat has been cooked into the rest of the food.

PROTEINS

Carbohydrates and fats are the chief sources of energy for the activities of the body but not the chief constituents of which the active tissues are composed. Muscle tissue, for example, contains but little carbohydrate, and often very little fat. The chief organic constituents of the muscles, and of the protoplasm of plant and animal cells generally, are substances which contain nitrogen and sulfur in addition to the carbon, hydrogen, and oxygen of which the carbohydrates and fats are composed. In 1838, the Dutch chemist Mulder separated and described a nitrogenous material which he believed to be the fundamental constituent of tissue substances and gave it the name *protein*, derived from a Greek verb meaning "to take the first place." While Mulder's chemical work did not prove to be of permanent value, the term which he introduced has been retained, and in the plural form, proteins, is now used as a group name for a large number of different but related nitrogenous organic compounds which are so prominent among the constituents of the tissues and of food that they may still be accorded some degree of preeminence by the student of nutrition.

The protein molecule is very large and complex, composed essentially of a great number of comparatively simple units, the *amino acids*. When proteins are digested the amino acids are set free. Typically there are formed a number of intermediate products *proteoses*, *peptones*, etc. (corresponding to the dextrins and maltose in the digestion of starch) and ultimately the simple amino acids as final digestion products (corresponding to the monosaccharides which are the final products of the digestion of carbohydrates). Thus the relation of amino acid to protein is analogous to the relation of glucose to starch. There is, however, the important differ-

ence that the glucose molecules yielded by starch are all alike while the amino acid molecules yielded by proteins are of several different kinds.

Nutritional characteristics of the different kinds of amino acids will be studied in Chapter VI.

It is believed that in general the protein in each kind of tissue of each species of plant or animal is chemically distinct from the protein of every other tissue and species. When one considers that each molecule of protein may contain several hundred amino-acid units of as many as twenty-one different kinds, this almost unlimited number and diversity of the proteins in nature becomes in some measure understandable.

Plants synthesize their own proteins from inorganic materials obtained from the soil and air. Animals, on the other hand, must depend for material from which to build their tissue proteins upon the digestion products of the proteins of their food. Some of the amino acids are convertible into each other and so need not individually be furnished by the food proteins. Others, which contain characteristic chemical structures or groupings that the body cannot obtain from other sources or synthesize for itself, must be supplied in some form in the nutriment. These latter, which are frequently designated as the *indispensable* or *nutritionally essential* amino acids will be discussed more fully in the study of protein requirements in nutrition and the relative merits of different foods in meeting these requirements (Chapter VI).

DETERMINATION OF PROTEINS, FATS, AND CARBOHYDRATES IN FOODS

Actual descriptions of the methods of food analysis lie outside the scope of this book. The purpose of the paragraphs which follow is simply to indicate enough of the general plan to give a reasonable feeling of acquaintance with the meaning of the percentages as used in subsequent chapters and as tabulated in the Appendix.

Protein.*—Not only do all proteins contain nitrogen; they all contain not far from 16 per cent of nitrogen, and most foods contain only insignificant amounts of other nitrogen compounds. Hence, to find the amount of total protein which a food contains, one may determine the amount of nitrogen and multiply this by 6.25.

Fat.—A weighed portion of the air-dry, finely ground, sample of food is dried until completely water-free; then extracted with water-free ether (or other fat-solvent), the solvent evaporated, and the fat weighed. The figure thus found is usually a little higher than the true percentage of fat because of the simultaneous extraction of other substances which are soluble in the fat, or the fat-solvent, or the mixture of the two. This, however, is a relatively small source of error, particularly in the foods which are important sources of fat.

Carbohydrate.—While there are analytical methods by which each of the more important carbohydrates of our food may be determined individually when necessary, it is often considered sufficient to determine total carbohydrate "by difference," *i.e.*, by subtracting from the total percentage of organic matter in the food the percentages of protein and fat found as above. This of course involves determinations of water and ash in order that the total organic matter of the food may be known.

Water is determined by drying to constant weight, and ash by burning off the organic matter of the dry food and weighing the residue of mineral matter, both the operations and the interpretations requiring the observance of technical precautions the full discussion of which would lead us beyond the scope of this book.

EXERCISES

1. Why are the sugar cane and the sugar beet the two economically outstanding sources of the world's supply of sugar?

*When, as in the case of the proteins, the fats, or the carbohydrates, the members of a related group admit of a generalized statement, the collective-singular form of the group name is commonly used.

2. Using the library facilities available to you, prepare an account of one or more of the following: the growing and harvesting of sugar cane or sugar beets; the making of raw sugar from cane or beets; the refining of the raw sugar into the white crystallized sugar (granulated or domino sugar) of commerce; the present-day corn sugar industry.

3. Compare present per capita sugar consumption of your country with that of others; and with that of two generations ago.

4. Examine food starches under the microscope.

5. What sugars and sirups are made from what starches on an industrial scale? To what countries and to what times does your answer refer?

6. Compare the starch contents and the sugar contents of potatoes and sweetpotatoes. (We do *not* write "white and sweet potatoes," because botanically the socalled sweetpotato is not a kind of potato. They belong not only to different species but to different genera. What are their scientific names?)

7. How do potatoes and sweetpotatoes differ with respect to other nutrient factors? Is more of nutritive value lost in the making of starch from one than from the other? (Use the index; also other books.)

8. Why have we an industry of hydrogenation of fats, which changes unsaturated into saturated fatty acids, when the "nutritionally essential" fatty acids belong to the unsaturated group?

9. Look up, in reference tables at the back of this book or elsewhere, a number of foods containing percentages of protein which you judge to be important in view of the extent to which the food enters into the average dietary. Note the percentages both of protein and of water (moisture) in the edible portion of the food as listed; then compute the percentage of protein in the dry (water-free) matter in each case. Comparative compositions of foods are expressed sometimes on the water-free basis, more often on the basis of the condition, moist or dry as the case may be, in which each food is ordinarily obtained from the market by the consumer.

10. Using the record of your food (Exercise of Chapter I), amended if necessary by substituting simple foods for mixtures of unknown composition, compute your daily intake in grams of carbohydrate, of fat, and of protein. (In the next chapter we shall study what happened to these foodstuffs after you had eaten them.)

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Chapter III

WHAT HAPPENS TO FOOD IN THE BODY: DIGESTION AND METABOLISM

What we have now to consider is how the foodstuffs studied in the preceding chapter are brought into the actual nutritional service of the body.

Digestion is the general name for the processes by means of which the carbohydrates, fats, and proteins of the food are brought by the body into forms fitted for absorption from its digestive tract into its true interior,—the blood and lymph, the organs and tissues.

Metabolism (derived from a Greek word the literal meaning of which is merely "change") is used by the science of nutrition as a general name for the changes which the digestion-products undergo from the moment of their absorption until they have reached the end products of the nutritional process.

The same terms thus applied to the food as a whole may also be applied to a single kind of nutrient, as when we speak of the digestion and metabolism of carbohydrate; or of fat; or of protein.

Digestion

The process of digestion of the food as a whole may be said to have four general effects: (1) it brings the digestible constituents of food into fluid form; (2) it changes the more complex sugars and the starches into sugars of the simplest type, "monosaccharides"; (3) it changes fats into a mixture

of glycerol and fatty acids; (4) it changes proteins into a mixture of amino acids.

The significance of these digestive changes is of a two-fold kind. It facilitates the absorption of the nutrients; and it results in their being absorbed in the form of their simplest "building-blocks," from which the body tissues can reconstruct carbohydrates, fats, and proteins according to their own patterns.

Or instead of rebuilding the digestion-products of the foodstuffs into the corresponding tissue-stuffs, the body may use the digestion-products as fuel.

Enzymes

The changes which the foodstuffs undergo in digestion and metabolism are facilitated and greatly hastened by the presence (in the digestive juices and in the active cells) of substances known as enzymes.

By definition, *enzymes* are catalysts formed in living cells; and *catalysts* (or *catalytic agents*) are things that "act by contact," or more particularly they are things which act very

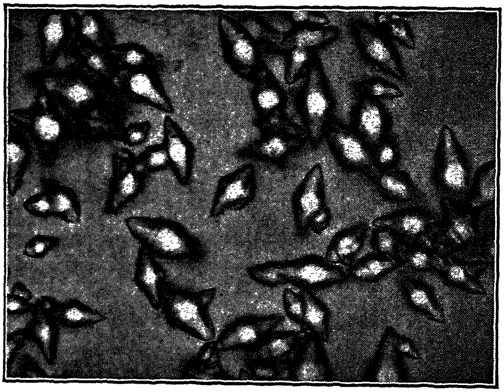

FIG. 5. Crystals of pepsin. Contrast with trypsin, shown in Fig. 6. Both are representative digestive enzymes, recently isolated in crystalline condition, both typically protein in their chemical nature, but of very different crystalline form. (*Courtesy of Dr. J. H. Northrop.*)

significantly in bringing about chemical changes without themselves being used up in the reaction.

In theory, such a catalyst is regarded as speeding-up a change which would otherwise go on only slowly. In practice, the enzyme may make all the difference between a rapid rate of change and a rate which is infinitely slow. Hence one often speaks *as if* the enzyme were responsible for initiating the reaction which it catalyzes.

Thus the enzymes are characterized by their ability, even in very small amounts, to accelerate changes in other substances. The typical enzymes are *specific* both as to the substance on which each acts, often called its *substrate*, and with regard to the nature of the change which they catalyze.

Furthermore, enzymes formed in different organs of the body are apt to be at least slightly different in their own chemical nature, even in those cases in which they act in the same manner upon the same substrate. This is true, for example, of two enzymes which both take part in the normal

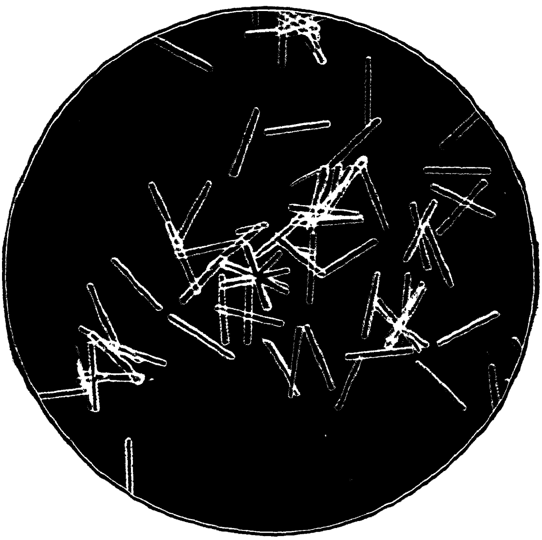

FIG. 6. Crystals of trypsin.
(*Courtesy of Dr. J. H. Northrop.*)

digestion of starch; and these will serve to illustrate the modern system of naming enzymes.

The name of each enzyme, in so far as these names have been coined *recently*, is constructed from the name of the substance upon which it acts, with the suffix *-ase;* and the noun thus formed is preceded by an adjective indicating the source of the enzyme. Thus in the present example, as the classical name of starch is *amylum*, the starch-digesting enzymes are called *amylases*. The one contained in saliva is called *salivary amylase* and the one in pancreatic juice is called *pancreatic amylase*.

Enzymes which digest fats are called *lipases;* those which digest proteins are called *proteases*.

There are, however, several important instances in which names assigned before this plan of nomenclature had been decided upon still continue in common scientific use, as, for example, *pepsin* for what according to the formal system would be called *gastric protease*.

In this chapter, we shall be chiefly concerned with the enzymes which act upon food in its course through the alimentary tract. Most of these are *hydrolytic* enzymes, *i.e.*, they accelerate processes in which the elements of water enter into the process of splitting of the foodstuff into its digestion products. The most thoroughly studied of these digestive enzymes have all been found to be typical proteins. In Figs. 5 and 6 are shown crystals of two typical digestive enzymes, pepsin and trypsin, prepared in a purified condition by Northrop and his coworkers.

A tabular summary of all the well-known digestive enzymes is given in the Appendix.

For our present purpose the essential point is that the digestive enzymes (sometimes called "digestive ferments") result in the breaking down of the carbohydrates, fats, and proteins of the food into digestion-products which (1) are more soluble and diffusible and thus more available to the body cells, and (2) are simple enough to be readily used as building-stones in the chemical architecture of the body sub-

stances or to function readily as fuel for the support of the energy needs of nutrition.

The Course of the Food through the Digestive Tract

For our present purpose, the digestion of foodstuffs may perhaps best be studied by first tracing the course of the food as a whole through the digestive tract and then taking up in turn the fate of the carbohydrates, the fats, and the proteins, both in digestion and after absorption.

The digestive apparatus includes the *alimentary tract*,—essentially a tube about 30 feet long in a grown person,—and the *glands* whose secretions are poured into the alimentary tract and assist in the transformations taking place there. The general features of the arrangement of this mechanism are familiar to almost everyone, and are shown diagrammatically in Fig. 7. As will appear in the discussion

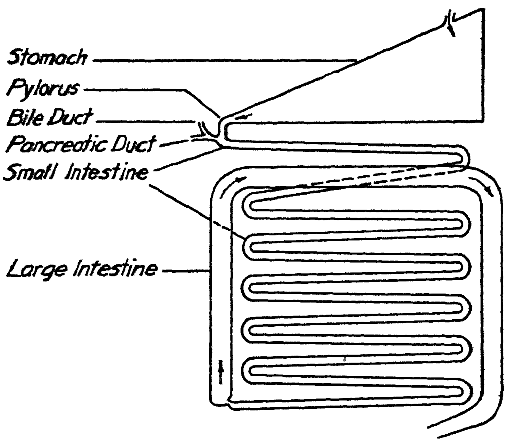

FIG. 7. Diagram of the digestive tract, representing schematically the relative position of the stomach, the small intestine, and the large intestine; and indicating the point at which the digestive secretions of the liver and the pancreas enter.

which follows, this system of organs is specifically adapted to perform efficiently both the *mechanical* or *physical functions* of grinding and shaking the food-masses until finely divided

and thoroughly mixed with the digestive juices; and also the *chemical function* of providing digestive enzymes and surrounding them with conditions favorable to their activity.

In the course of normal digestion these functions in the different parts of the digestive system are coordinated partly through the nervous system and partly by the sending ahead of "chemical messengers" (hormones) to prepare the digestive apparatus for the oncoming load of food material. Thus, the taste of food (or often the very thought of it) may initiate the secretion of digestive juices not only in the mouth but also in the stomach. And as soon as the stomach begins to allow the passage of the partially digested food mixture into the small intestine, a chemical messenger (called *secretin*) is sent from the intestinal membranes by way of the blood stream to the pancreas and liver, exciting these organs to increased production of fluids which are discharged into the small intestine and assist in the digestive processes there.

As indicated by the heading of this section, what follows is an account of what goes on in the successive organs of the digestive tract. The description refers, first, to the mechanical handling of the food-mass as a whole and, second, to the chemical changes which occur in the carbohydrates, the proteins, and the fats of the food. These are, of course, the physical and the chemical aspects of what the digestive tract does to the food. The converse question from this viewpoint is, what the food does to the digestive tract or to the process of digestion.

As one follows the course of the food through the digestive tract it should be with two aspects of thought in mind: How should the person treat the digestive system, especially as to what is swallowed and in what circumstances; and what service may then be expected from the digestive system.

The scope of this book does not include the study of disorders of digestion. The following outline therefore presumes that we are dealing with a well-treated and well-behaved digestion.

In the mouth the food should be not merely softened and lubricated so that it can be swallowed easily; it should be chewed thoroughly to reduce it to particles of the smallest size and to mix the saliva intimately through every bit of the food mass. Only when the food has been chewed until reduced to very small particles can the different digestive juices act upon it to best advantage. In the mode of attachment of the jaw and in the strength of its muscles, we are provided by nature with an ample and efficient mechanism for the proper chewing of our food. But nature has made chewing a voluntary act; thus leaving it to our own intelligence and will to determine the thoroughness with which this first act of the digestive process shall be performed. Such rules as that one should chew a given number of times upon each mouthful may be helpful, but are too mechanical to satisfy one who takes an intelligent interest. A more rational though perhaps somewhat more extreme rule is that each mouthful should be chewed as long as any taste can be perceived or until swallowing is entirely unconscious. It is a mistake to suppose that such thorough chewing greatly reduces the amount of food required; but for other reasons it is an excellent habit.

While the food is in the mouth, the several groups of salivary glands pour out their secretion upon it. This saliva is the only digestive juice which ordinarily comes directly under our observation, and perhaps because it is familiar we are apt to underestimate its significance. We say that a tempting dish "makes the mouth water," and are apt to think of this as a property of the food rather than as an important first step in digestion. The actual part played by the saliva in the process of digestion is much greater than was formerly supposed. The saliva has no appreciable action upon proteins or fats but does digest starches and dextrins by means of an enzyme known as ptyalin (or more recently as salivary amylase) which is active in approximately neutral solutions. Although relatively little chemical change in the food actually takes place in the mouth, under favorable con-

ditions the salivary amylase may continue to act on food carbohydrates in the stomach for some time before the acid gastric secretion reaches it in sufficient amount to halt its activity.

To end a meal with (or to follow a meal by) the eating of raw fruit or celery, when one can conveniently arrange to do so, is an excellent habit for several reasons. The discussion of the ultimate nutritional benefit belongs to later chapters; but some of the more immediate advantages should be noted here. The combined mechanical action of the vegetable fiber and chemical action of the mild fruit acid leave the mouth in the best possible condition with a sensation of savory cleanliness and toning up which is well worth while in itself; and which also sends nerve impulses and chemical messengers which greatly aid the successive steps in the digestive process.

In the stomach, the food is stored for a longer or shorter time depending largely upon the size and character of the meal. The walls of the stomach are so elastic that, as expressed by Howell, there is "never any empty space within; its cavity is only as large as its contents, so that the first portion of food eaten entirely fills it and successive portions find the wall layer occupied and are therefore received into the interior." There is thus no general circulation and mixing of the stomach contents during or immediately following a meal. This was well illustrated in an experiment in which a rat was fed a liberal meal in three courses, each food of a different color. This animal was then killed, frozen, and the stomach contents examined. The food which had been eaten first lay next to the wall of the stomach and filled the part of the stomach which connects with the intestine, while the food last eaten lay in the interior of the stomach contents near the point at which it had been pushed into the stomach by the act of swallowing. Fig. 8 represents somewhat diagrammatically the relative position of food portions in the stomach during normal digestion according to the sequence in which they were eaten.

Not much nutriment is actually absorbed from the stomach, although some such absorption occurs in the case of such things as the monosaccharides and the soluble salts of the food which as swallowed are already in the forms in which they will be absorbed. A larger factor, in quickness with which nutriment is absorbed in any important quantity, is the promptness of its passage through the stomach and into the small intestine whose wall is a much more effective absorbing surface.

As all food-masses should be thoroughly moist throughout when they are swallowed, and in the stomach are further wetted by the gastric juice, the water (or solution of foodstuff in water) which is swallowed as such during a meal need not soak into the whole foodmass in the stomach but may (and largely does) find its way along the "lesser curvature" of the stomach wall* from the oesophagus to the pylorus, and thus pass more quickly into the small intestine than does the bulk of either the protein, the fat, or the carbohydrate of the ordinary solid food.

As in the case of any other organ, a detailed study of the functions of the stomach would involve a knowledge of its structure. Omitting all but what is essential to our present purpose, we may speak of the stomach as consisting of: (1) a larger part called the *fundus* or *cardiac region*, into which the food is received when swallowed, and which is very elastic and becomes distended as the stomach stretches to accommodate more food; and (2) the *antrum* or *pyloric region*, a much smaller part, conical in shape, and ending in the *pylorus*, the muscular valve which connects the stomach with the small intestine. A region of especially thick circular muscle fibers known as the *transverse band* is considered as marking the boundary between the cardiac and the pyloric regions of the stomach. (Fig. 8.)

By mixing some harmless mineral substance such as bismuth subnitrate with the food it becomes possible to

*The shape and position of the stomach are such that Fig. 8 may be regarded as about equally a vertical or a horizontal section.

observe the contour and movements of the food mass in the digestive tract by means of the x-ray. In this way it was shown that only in the pyloric region are the food masses and the gastric juice actively mixed by muscular contractions (See Fig. 8); in the fundus the swallowed masses of food and saliva remain comparatively undisturbed, so that in this part of the stomach the salivary digestion of starch may continue for a relatively long time.

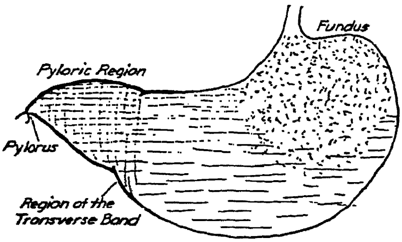

FIG. 8. Diagram of the stomach and the status of its contents during digestion. The position of the food last swallowed is here indicated by the speckled area, that of the intermediate portion of food by the horizontal shading, whereas the food first eaten, which has been pushed into the pyloric region and there thoroughly mixed with the gastric juice, is represented by the cross-hatched shading. The stomach wall is thicker and much more muscular from the region of the transverse band to the pylorus, while the wall of the fundus is relatively thin, passive, and elastic.

In the region of the transverse band there is, during digestion, a rather copious secretion of strongly acid gastric juice, and it is in this same region that waves of muscular constriction are seen to originate and from which they travel toward the pylorus. But the pylorus does not open at the approach of each of these waves and the material caught between the muscular wave and the closed pylorus is subjected to pressure and to an eddying movement which mixes it and reduces it to a creamy *chyme*. As the food thus becomes mixed with the acid secretion, salivary digestion of starch ceases and the digestion of protein is begun by the enzyme *pepsin*, which requires an acid medium for its activity. There is also present in the gastric secretion a fat-splitting enzyme (*gastric lipase*), but its activity under the conditions usually prevailing in the stomach is rather limited. The flow of gastric juice is affected by many factors, prominent among which are appetite for the food, pleasurable sensations when the food is being chewed, freedom from emotional tension, and

the presence in the stomach of certain substances including water, dilute acids, fruit and meat juices, and many other food constituents which have stimulating effects upon gastric secretion. This fact affords sound scientific justification for the common practice of beginning a meal with a dilute (watery) yet stimulating first course such as soup or fruit.

The free hydrochloric acid of the gastric juice has not only a digestive but also an antiseptic function, for this acid is a fairly efficient germicide. If the food, by thorough chewing, has been broken into very small particles so that any bacteria which it contains are freely exposed to the gastric juice, the latter will afford a much more effective protection against the passage of objectionable bacteria through the stomach into the intestine than is possible when some of the food particles are too large to be completely permeated by the acid during the short time that the acid chyme remains in the stomach.

At intervals the pylorus opens and permits the passage of chyme into the small intestine. As the food in the pyloric region is thus gradually passed out of the stomach, fresh portions of the food mass in the fundus are pressed into the antrum by the muscular tension of the stomach wall.

Thus, while the dividing line is not sharp nor prominent there is a fairly distinct difference both in structure and function between the two regions of the stomach: In the thin-walled elastic fundus the food mass is held quietly in storage and salivary digestion of starch continues; in the thick-walled antrum with its peristaltic waves of muscular constriction the food is mixed with the gastric juice, salivary digestion ceases, peptic digestion of proteins begins, and the food is more or less thoroughly disinfected by the free acid of the gastric juice.

The stomach as a whole may therefore be said to have four main functions. It serves: (1) as a storage reservoir receiving food in relatively large quantities, say three times a day, and passing it on to the intestine in small portions at frequent intervals; (2) as a place for the continuation of the salivary digestion of starch; and (3) for the beginning of the

digestion of proteins and perhaps fats; and finally (4) as a disinfecting station of somewhat doubtful and variable value since the food is subjected to the acidity of the gastric juice for a relatively short time in the pyloric region, and the degree of contact of acid with bacteria must depend largely upon the size of the food particles at this stage of digestion.

The length of time spent by food in the stomach depends in part upon the proportions of carbohydrate, protein, and fat eaten. In experiments where each is eaten separately, protein food stays longer in the stomach than carbohydrate; fat longer than protein; and mixtures of fat and protein longest of all. In a mixed diet, then, the greater the proportion of fat the longer the food stays in the stomach. This action of fat may be either disadvantageous or advantageous according to circumstances. Excessive fat may retard digestion unduly and lead to discomfort; on the other hand, too little fat may result in such early emptying of the stomach that hunger pangs are felt too shortly after the meal is eaten.

In the small intestine, the food, which (as we saw) has already been reduced to a liquid chyme, is subjected to the simultaneous action of three different secretions, the bile, the pancreatic juice, and the intestinal juice (or *succus entericus*). These three secretions all contain alkaline salts which quickly overcome the acidity of the chyme so that the intestinal contents as a whole are normally alkaline. The bile does not seem to exert any direct digestive action but by its solvent and dispersive action on fats and fatty acids it not only assists the fat-splitting enzymes to come into more effective contact with their substrate, but also facilitates the absorption of the fatty acids formed as the result of their activity. Pancreatic juice contains digestive enzymes for each of the three groups of foodstuffs—proteins, fats, and carbohydrates. The intestinal juice takes part in the digestion of both proteins and carbohydrates. For fuller information regarding the specific enzymes involved, Table 25 in Appendix B may be consulted.

In the upper part of the small intestine there occurs a

special sort of muscular contraction which quickly emulsifies the fat by shaking it back and forth with the alkaline juices and bile, at the same time promoting the digestion of all of the foodstuffs by bringing them into intimate association with their digestive enzymes and facilitating absorption by constantly pressing fresh portions of the digesting mixture against the intestinal wall. In addition to this peculiar movement which is characteristic of the upper part of the small intestine, there occurs throughout its length a succession of peristaltic waves of muscular constriction which force the food mass against the absorbing surface and move it onward along the digestive canal. In the wall of the small intestine there are many cross-folds and innumerable tiny projections (*villi*) extending, like the fingers of a glove, into the central cavity (the *lumen*), which enormously increase the area of surface with which the digested food mixture comes into contact and facilitate the transfer of digestion products from the lumen of the intestine to the circulating fluids of the body, the blood and the lymph. For, in addition to the reasons already suggested, every wave of muscular pressure tends to force the blood and lymph from the villi onward into the body to be replaced by fresh blood and lymph from the general circulation (and with renewed avidity for the digestion products) as soon as the muscular wall relaxes again. The small intestine, with its abundance of enzymes and exceptionally favorable mechanical conditions, is thus well adapted to the processes of digestion and absorption and it is here that the greater part of the digestion products of the three major groups of organic foodstuffs are absorbed. From observations on a patient whose digestive processes were apparently normal it was found that 85 per cent of the protein of the food had been absorbed before the food left the small intestine; absorption of the other foodstuffs is presumably equally complete.

In the large intestine, the digestive juices continue to act upon the remnants of the foodstuffs and a further absorption of digestion products takes place, along with a very marked

absorption of water. The material remaining unabsorbed gradually becomes more solid and takes on the character of feces. A comparatively long time (often 18 hours or more) may normally elapse between the entrance of the digestion mixture into the large intestine and the elimination of the residual material from the body.

Fate of the Individual Foodstuffs in Digestion and Metabolism

The changes which some of the more prominent organic constituents of the food undergo in digestion and after absorption may now be considered individually. As a detailed treatment of the processes of intermediary metabolism would involve a somewhat technical knowledge both of organic chemistry and of physiology and require more space than is available here, we shall outline only those aspects an understanding of which is requisite to the purpose of this book, *viz.* the adaptation of food to the service of the body.

Absorption and Metabolism of Carbohydrates

The carbohydrates of the food, having been brought by the digestive processes to the form of monosaccharides, are taken up from the lumen of the intestine by the cells of the intestinal mucosa and passed, so to speak, into the "physiological interior" of the body. Most of the absorbed carbohydrate is transported from the intestine to the liver by way of the portal vein. In the liver, much of the carbohydrate is removed from the blood stream, glucose, fructose, and galactose each being converted into the polysaccharide *glycogen* for storage in that organ.

The glycogen reserve of the liver is subsequently hydrolyzed (always to glucose, regardless of the monosaccharide from which it was originally synthesized) and glucose is supplied to the blood to replace the carbohydrate which has been removed from it by other tissues of the body. The liver thus functions to maintain nearly constant the level of glucose in the blood of the general circulation, preventing

large increases, for example during the influx of carbohydrate after a meal, and counteracting the depletion of blood carbohydrate by other active tissues through releasing its store as needed. The concentration of carbohydrate in the liver, on the other hand, is subject to enormous variations, reaching as high as 10 per cent of the weight of the liver after an abundant meal and falling to nearly nothing when no carbohydrate food has been taken for some time.

The carbohydrate stored in the liver after a meal is thus usually converted into glucose and passes into the blood stream before the next meal, but still the glucose content of the blood remains small and nearly constant. This indicates that the glucose of the blood must be quite rapidly used, and, from the standpoint of our present study, the immediate question is, What becomes of the glucose which the blood carries away from the liver? Investigation shows that this glucose disappears chiefly in the muscles. There, glucose is converted into glycogen, which may reach a concentration of two per cent of the weight of the muscle. This glycogen plays an essential part in the complicated chain of chemical reactions through which energy is released for muscular work. Not all of the steps involved are clearly understood, nor is a detailed discussion of them appropriate to this book. However, it is known that, when a muscle contracts, a part of its glycogen is broken down to the three-carbon compound, lactic acid, a change which liberates energy. Still more energy becomes available when a part of the lactic acid so formed is oxidized to carbon dioxide and water.

Other active tissues of the body also withdraw glucose from the circulation, oxidizing it directly or indirectly as fuel for the various kinds of work which they perform.

Carbohydrate in excess of what is immediately burned and of what is stored as glycogen is converted into fat, which is a much more concentrated form of fuel and which can be stored in much larger quantity than can glycogen. Thus, under the most favorable conditions of feeding and

rest, the maximum amount of glycogen stored in the entire adult body is only about two-thirds to one pound, no more carbohydrate than is frequently taken in one day's food, and only about enough, if it were the sole source of energy, to support the body for one day. Whereas, it is a matter of everyday observation that the storage of fat may reach many pounds; and a well nourished individual carries in his body enough fat to serve him as fuel for a month or more.

Digestion of Fats

Before it can be absorbed from the intestinal tract, the fat of the food apparently must be split into its components, glycerol and fatty acids. This cleavage takes place through the action of fat-splitting (lipolytic) enzymes known as *lipases*. There is a lipase in the gastric secretion, but this can effectively digest only fat which has been eaten in a highly emulsified (finely subdivided) condition. The remainder of the fat, after becoming thoroughly emulsified in the small intestine by the vigorous agitation with bile and alkaline salts to which it is there subjected, is readily attacked by the lipase in the pancreatic juice.

Absorption and Metabolism of Fats

The fatty acids and glycerol which are formed in the digestion of fat recombine into fat in the process of being transferred through the cells lining the intestinal tract. This fat passes mainly into the lymph vessels (rather than the blood vessels) and is finally poured with the lymph into the blood, without first having been through the liver. This results in a rise in the fat content of the blood of the general circulation which is much more marked than the increase in glucose concentration following absorption of carbohydrate. The fat thus distributed through the body may be burned in the muscles and other active tissues as a source of energy for muscular and other forms of work; or, if not needed at once as fuel, it may be deposited as body fat, a stored fuel ready to be drawn upon when needed.

Regarded as sources of energy, the functions of fat and carbohydrate are essentially the same, although the utilization of carbohydrate for the performance of muscular work appears to be slightly more efficient than that of fat. Furthermore, as we have seen, the body can change carbohydrate into fat to an almost unlimited extent. To what degree the body can change fat back into carbohydrate, we do not know with certainty; but since, within wide limits, fat serves the same purposes as carbohydrate, our study of the uses of the foodstuffs in nutrition does not necessitate an answer to this latter question.

The fact of the essential interchangeability of fat and carbohydrate in the support of body work greatly simplifies dietary calculations, since in many cases where we deal with the energy values of foods we need not stop to consider separately how much of the energy comes from fat and how much from carbohydrate. But this fact does not justify an attitude of total indifference toward fat as a dietary constituent, for, as already mentioned in Chapter II, recent work has shown that, although the body can build fat from carbohydrate and protein, it either lacks altogether the ability to synthesize linoleic acid, or can form it to only a very limited extent. And since this fatty acid is indispensable to the normal functioning and development of the body, it (or closely related linolenic acid) must be supplied in the food, and is, in this sense, "nutritionally essential." Furthermore, it was also explained that a diet devoid of fat would almost certainly be too lacking in "staying" qualities to satisfy persons who eat only three meals a day; and some physiologists hold the view that the human gastrointestinal tract is too short to handle with maximum efficiency the large masses of food that would be needed to supply energy if fat, the foodstuff of most concentrated energy value, were excluded from the diet.

A part of the fatty acids obtained from the fat of the diet or synthesized from carbohydrate is utilized in the formation of constituents of many of the active tissues of the

body. To this extent at least, the fats may be regarded as tissue-building materials.

However, most of the fat of the well nourished body represents reserve fuel, and as such is deposited in the metabolically inactive adipose (fat-storing) tissues. This storage of fat may occur in many regions of the body, but is particularly marked just below the skin, where a layer of fat of variable thickness may usually be found. Stored fat is also present between the muscles and surrounding the internal organs. Fat thus deposited, although of principal significance as a reserve source of energy, may also serve the body as a mechanical protection against shocks and bruises, as a comparatively impervious blanket against the cold, and as a packing and support for certain of the organs, notably the kidneys.

Usually the nature of the fat found in the body is more or less characteristic of each species or group of closely related species. Herbivora contain as a rule harder fats than carnivora, land animals have harder fat than marine animals, and all warm-blooded animals have fats of higher melting points than those found in fishes. The nature of the body fat may also be affected by the diet. Under many conditions of feeding, the major part of the body fat may be synthesized from carbohydrates. If, however, much of the body fat is formed from fatty acids present in the food, and these differ markedly either in kind or in relative proportions from the mixture of fatty acids which that species of animal normally synthesizes from carbohydrate, these differences may be reflected to some extent in the kind of fat deposited in the body.

Nevertheless, although the body fat may thus differ somewhat in its chemical character accordingly as it is derived mainly from dietary carbohydrate and protein or mainly from dietary fat, its nutritive value appears to be essentially the same. In either case, the fat thus stored may be drawn

upon for use as fuel at any future time when the energy requirements of the body demand it.

Digestion of Proteins

The saliva does not digest protein and, so long as the swallowed food remains in the muscularly inactive region of the stomach and unmixed with the gastric juice, the protein is unchanged. Little by little, however, as explained earlier, the food becomes mixed with the gastric juice, which is rich in hydrochloric acid and the proteolytic enzyme, pepsin. Together, these attack the protein of the food, changing it into the somewhat simpler, but still very complex, proteoses and peptones. The proteoses and peptones pass into the small intestine where they (and any protein which may have escaped the action of pepsin) are exposed to a whole battery of other proteolytic enzymes, of which one group, formerly designated as "trypsin" (but now known to consist of at least three distinct enzymes), is provided by the pancreas, and another group, originally referred to in the singular as "erepsin" (but actually consisting of at least two separate entities), is secreted by the intestinal mucosa. Acting cooperatively in the small intestine, these numerous separate enzymes complete the cleavage (hydrolysis) of the protein, proteoses, and peptones received from the stomach, into their ultimate component units, the amino acids.

Absorption and Metabolism of Amino Acids

It is now believed that the hydrolysis of proteins to amino acids in the digestive tract is, in normal conditions, practically complete. The protein digestion products are absorbed, mainly from the small intestine, into the blood stream, and distributed as amino acids to the various tissues of the body. The amino acids, having been withdrawn from the blood stream by the tissues, may be used by them in various ways. (1) Part may be reassembled as building stones to form new

protein in the proportions and according to the specific pattern characteristic of the tissue in question. (2) Some may be assimilated to take the place of fragments of body protein which are being broken down in the wear-and-tear processes which always go on in living cells. (3) Certain of them may be utilized in the synthesis of substances (some protein in nature, others of simpler composition) such as certain hormones and enzymes, which have essentially body-regulating rather than structural functions. (4) The remaining are broken down ("deaminized") into a nitrogenous fragment, which is eliminated from the body chiefly in the form of urea, and a non-nitrogenous residue, which is either burned as fuel or converted into carbohydrate or fat. Similar "metabolites," formed in the wear-and-tear processes from body protein are used in the same way. In serving as fuel, the protein is utilized interchangeably with carbohydrate and fat, since its energy may be converted into muscular work, internal activity, or heat.

In the growing child, there is extensive construction of new tissue and an important fraction of the food protein may be required to meet this need. Once the individual has achieved his full growth, however, there is little or no further accumulation of protein (except in special cases as, for example, in pregnancy, or during recovery after a severe wasting disease, where actual construction or reconstruction of body tissue is involved, or when, as the result of increased muscular exercise, a real enlargement of the muscles occurs). It is therefore ambiguous and may be misleading to state that the amino acids resulting from digestion of food protein may be used for purposes of tissue repair *or* be burned as fuel; for that fraction which is used in the repair process is in general not *added* to the body's store but simply *exchanged* for an equal amount of material which is being broken down and burned. Hence, all the protein or amino acid which the full grown body assimilates is, unless new tissue is forming, sooner or later burned as fuel, whether or not it first serves for the repair of body structure.

Summary of the Fate of Foodstuffs

Carbohydrate may be
- Burned to yield energy: (*a*) for external muscular work; (*b*) for internal activity; (*c*) for heat
- Stored as glycogen
- Changed into fat

Fat may be
- Burned to yield energy: (*a*) for external muscular work; (*b*) for internal activity; (*c*) for heat
- Stored as fat
- Used in synthesis of tissue lipids
- Possibly to some extent changed into carbohydrate

Protein may be
- Used in building or repair of protein tissue
- Used in synthesis of certain hormones, enzymes, and other body regulators
- Deaminized and
- Burned to yield energy: (*a*) for external muscular work; (*b*) for internal activity; (*c*) for heat
- Changed into carbohydrate
- Changed into fat (possibly through carbohydrate).

Thus carbohydrates, fats, and proteins all serve as fuel to yield the energy of muscular and other forms of work, or to keep the body warm, and any or all of them when present in quantities more than sufficient to meet immediate needs may contribute to the production of fat which is the body's chief form of stored fuel and which is utilized in just the same way whether formed from the carbohydrate, the protein, or the fat of the food.

The body has very great power to convert one foodstuff into, or use it in place of, another; and so to economize its resources in this respect that the total energy value of the food is used to meet the total energy requirement of the body. In the next chapters we shall consider the more quan-

titative aspects of the problem of balancing the potential energy represented by the different items of the diet against the bodily expenditures of energy in its various forms.

EXERCISES

1. Using data tabulated in the Appendix, compute the number of grams (*a*) of protein, (*b*) of fat, (*c*) of carbohydrate, consumed on each of the days for which you previously recorded your food consumption.

2. What significance do you attribute to the daily variations?

3. If your record contains any food too rare or of too artificial a nature to be included in the appended reference tables, either make adequate inquiry as to its nature and composition* so as to be able to complete your calculation, or amend your "dietary" by the substitution of some food whose composition is better known.

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*See, for example, the extensive table of nutritive values of cooked foods in the Appendix of Rose's *Feeding the Family*, 4th Edition (1940).

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Chapter IV

ENERGY ASPECTS OF NUTRITION

Introductory Explanations

Every act and moment of life involves, in terms of formal physics, a *transformation*, or, in everyday terms, an *expenditure, of energy*.

We are fully aware of spending energy when we do active muscular work. When we rest, energy expenditure diminishes but does not stop. For, when you have relaxed as completely as you can, your body still has internal work to do. The muscular work of the heart and the work of the muscles of respiration involve significant amounts of energy within every minute; and the resting muscles still possesss some degree of tension (tone or *tonus*), the maintenance of which requires a considerable energy transformation or expenditure. The internal work of the body must go on so long as life continues. It is difficult to measure any one of the forms of internal work separately from the others; but it has been estimated that the heart alone (even when the person is lying perfectly quiet) does an amount of work *each hour* equivalent to the lifting of the entire body about 100 feet into the air; and the work of breathing usually involves a considerably larger expenditure of energy; while the amount of energy expended in maintaining the tension or tonus of the muscles is larger still.

The energy which the body "spends" appears so largely in the form of heat, that the science of nutrition finds it

convenient to express energy measurements in terms of the heat unit, the Calorie.

Physics makes use of two such heat units, one a thousand times greater than the other; and for brevity distinguishes the greater Calorie by writing it with a capital C while writing the lesser calorie with a small initial letter. The energy transformations in our bodies are always of such magnitude as to make the larger unit the more convenient, and it is practically always used in speaking or writing of the energy aspect of nutrition. As a technical term belonging primarily to physics, it should be written as the physicists write it, Calorie. But some writers and editors, growing weary of frequent use of the capital, have decided that in nutrition books there is no real danger of confusion if the existence of the lesser unit be simply ignored and the initial capital dispensed with in referring to the greater calorie inasmuch as this is the only one which need be used in nutritional discussions.

Hence in writings on nutrition the unqualified word, "calorie" will presumably mean the same as *Calorie*, *i.e.*, the greater calorie (or kilogram-calorie or kilo-calorie) which is *the amount of heat which raises the temperature of one kilogram of water through one degree centigrade.*

In this book the Calorie is given an initial capital in those cases (only) in which an explicitly quantitative statement is being made.

As a help in relating the scientific unit to our everyday measures, it may be noted that this is almost the same as the amount of heat which raises the temperature of one pound of water through four degrees Fahrenheit—or of four pounds of water through one degree Fahrenheit.

And it may also be helpful to remember that 100 Calories is about the amount of energy spent by a normal adult sitting (not *too* completely relaxed!) in a lecture-room or study chair for one hour.

While the unit of energy used in discussions of food values and nutritional needs has a direct and well-established

physical definition, the word *energy* does not always stand simply for the mechanical concept to which the physical definition applies.

It is a current statement that: "Energy is the ability to do work."

But as applied to our body and its nutritional needs, this short definition may have a double meaning, which, while it should not seriously mislead a student well-grounded in even elementary physics, is in fact confusing to many people. For our bodily "ability to do work" implies, in the literal everyday meaning of the words, *both* a supply of available fuel and a properly built and conditioned "mechanism" for the transformation of the potential fuel value into the effective activities of muscles and other bodily organs. It is to the first of these that we refer when we speak of the energy aspect of nutrition and the energy values of foods; but it is to the second that we are usually referring when we say that we "feel full of energy" or that we "lack energy." Thus the energy value of foods as expressed in calories is the energy of the purely fuel or merely mechanical sense; while our *fitness* is, or is directly related to, our state of being energetic in the colloquial or psychological sense.

Mental work may cause fatigue without any corresponding energy expenditure.

The difference finds frequent illustration in the daily lives of students and teachers. Usually at the end of a lecture-hour both the students and the teacher will be tired, fatigued, "lacking in energy," more or less depleted of their "ability to do work"—though probably no one "spends" (transforms) more than 100-150 Calories of energy in an hour in a classroom. If, then, after the lecture one goes for a walk one will probably spend twice as much energy (in the mechanical or calorie sense) in an hour, yet return feeling rested and energetic. A feeling of fatigue may be directly related to one's bodily condition without being proportional to expenditure of energy in the physical or mechanical or calorie sense. As

one usually speaks, "lack of energy" will generally be due to some suboptimal condition of one's bodily chemistry or internal environment; but not necessarily as the result of too much muscular work and energy metabolism—perhaps as a result of too little!

In this connection we might mention the hypothesis that each normal member of any given species has as a natural birthright the ability to spend about a certain total amount of energy in the course of a natural life time, so that the more energy one expends per year the fewer years he should expect to live. In an empirical form this hypothesis is a tradition of army teamsters who say, "There is so much work in a mule; you take it out of him faster or more slowly according to how hard you work him." Rubner, an influential expert in nutrition, held much the same idea as a formal scientific hypothesis. But to speak of how "hard" one works involves much the same ambiguity as to speak of energy as ability to do work. No doubt some human lives are shortened by excessive muscular work; but one may also shorten his life by working so "hard" at a sedentary occupation that he gets too little muscular exercise. In so far as one's work influences the length of one's life, it is probably not so much through rate of energy expenditure *per se* as through the effect upon the body's internal environment which may be unfavorably influenced either by overtaxing the muscles or by leaving them stagnant too much of the time.

Internal environment as a factor in nutritional well-being can be more clearly apprehended after we have studied the mineral elements and the vitamins as factors in nutrition. But meanwhile some ambiguities may be avoided if what has been suggested is kept in mind throughout the study of the energy aspects of nutrition and food values.

The Council on Foods of the American Medical Association includes among its general rules regarding advertising that the advertiser should correctly inform the public as to energy values of foods in such carefully chosen terms as

clearly to distinguish between "the caloric and the popular" senses of the word *energy*, which distinction, the Council declares, "must be recognized and observed."*

The Council also admonishes the advertisers of food products to "take cognizance of the fact that limitation of the energy intake is essential for reduction of body weight. There are no foods that burn up body fat."*

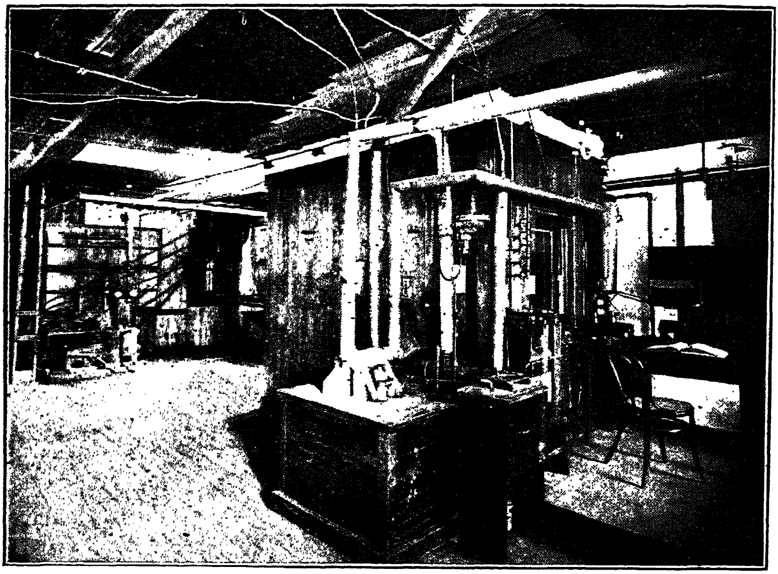

FIG. 9. Outside view of the original Atwater-Rosa-Benedict respiration calorimeter.

The use of the Calorie as a convenient energy unit does not imply that the body is a heat engine, though this faulty analogy has been used in the past.

At the end of the nineteenth century, some teachers thought that a reasonably satisfactory approach to the essentials of nutrition as then known could be made in terms of protein and calories, and by way of the steam engine as an analogy. The protein of the food was pictured as the

*Council on Foods 1939 Accepted Foods and Their Nutritional Significance, p. 23. (American Medical Association, 535 North Dearborn Street, Chicago.)

building material of the "mechanism"; and the energy value of the food, as corresponding with the calorific value of the fuel burned in the engine.

But the body is so emphatically *not a heat engine* that to

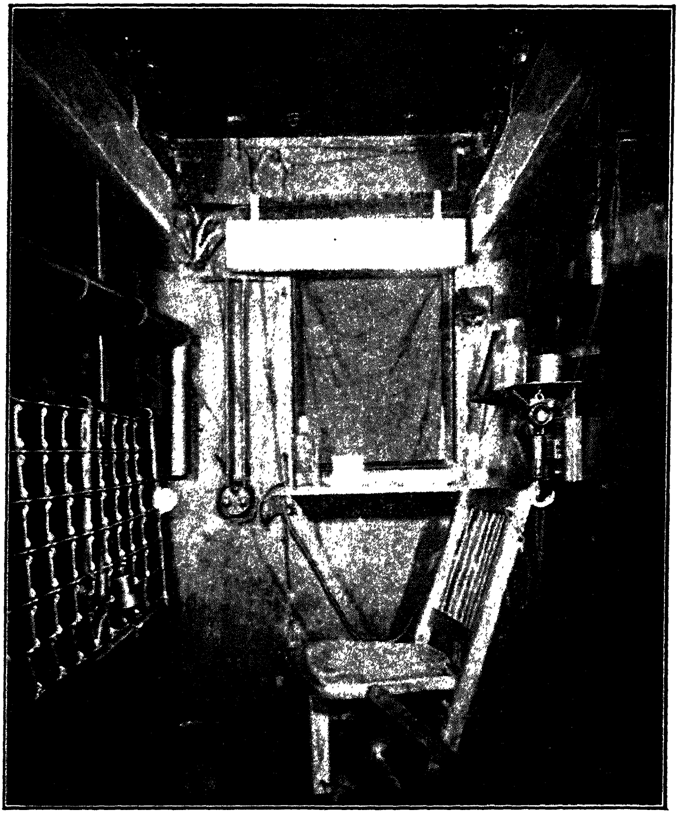

FIG. 10. Inside view of the original Atwater-Rosa-Benedict respiration calorimeter.

liken it to a steam engine is now realized to be misleadingly inadequate. Less inadequate, as well as more modern, is the analogy of the *gasolene engine* of an automobile or a motorboat; for in such a motor, as in the body, the heat is a by-product or end-product and not (as in the steam engine)

the means through which the potential or chemical energy of the fuel is transformed into useful work.

If, then, one desires to compare the body with an automobile engine, the protein and some of the mineral elements correspond to the structural material of the motor; other mineral matters, including water, correspond to the lubricants; such organic foods as the carbohydrates and fats, and

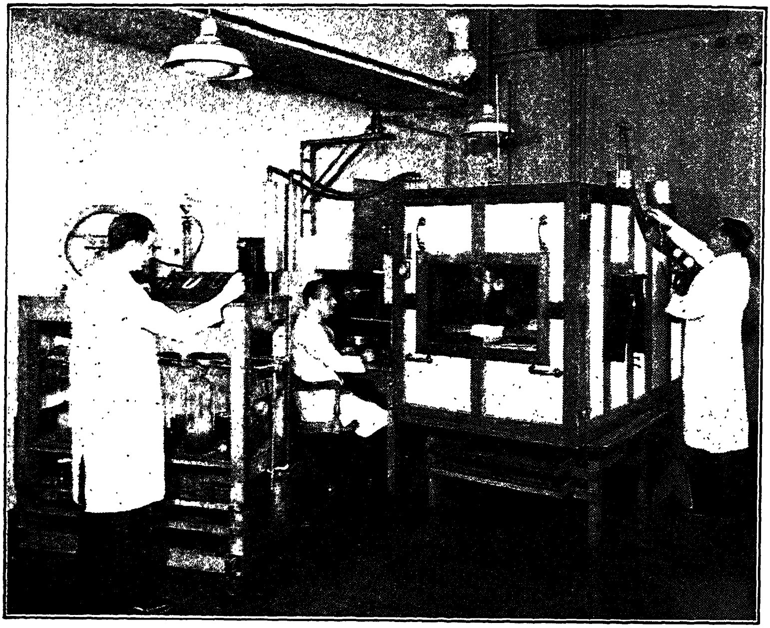

FIG. 11. The respiration calorimeter now in use at the Russell Sage Institute of Pathology. (*Courtesy of Dr. E. F. DuBois.*)

the non-nitrogen derivatives of the proteins, are the fuel; and the vitamins correspond to the ignition sparks, whose own energy value is insignificant, but without which this kind of engine cannot run, however abundant its fuel and however appropriate its structural materials and its lubricants.

Throughout the present discussion of the energy aspect of nutrition, we shall be assuming (unless otherwise specifically

stated) that the other nutritional requirements are being sufficiently supplied to meet normal needs, and that we are dealing with physiological rather than pathological conditions.

When one speaks of the amount of food required, it is usually the body's energy requirement, the *number of calories needed per day*, which *first* comes to the mind of the systematic student of nutrition; for to any extent that the intake of fuel is inadequate, the body must burn some of its own substance as fuel to meet its energy needs. Hence, generally speaking, the economy of other nutritional assets is fundamentally conditioned by the meeting of the body's energy requirement.

For the purpose of the present brief study of the body's energy needs, we may start with an average-sized healthy man at rest. Such a man, sitting comfortably in a chair, will as already mentioned spend about 100 Calories of energy per hour.

Methods of Measuring Energy Metabolism

Atwater-Rosa-Benedict respiration calorimeter and its successors.—At the turn of the century, the outstanding news in nutrition was that about "the man in the copper box," *i.e.*, the experiments with human subjects in the respiration calorimeter which had been developed and brought into successful use by Atwater, Rosa, and Benedict. (Figs. 9 and 10 are photographs of the exterior and interior of the original Atwater-Rosa-Benedict respiration calorimeter; while in Fig. 11 is shown a considerably later modification of this apparatus in use at present in the Russell Sage Institute of Pathology.)

The respiration calorimeter, as the name implies, is both a respiration apparatus for the chemical determination of the oxygen consumed and the carbon dioxide and water produced in the respiratory exchange, and a calorimeter for the direct measurement of the heat given off by the body.

The measurements were brought to a very high order of precision; and upon averaging the results of a large number

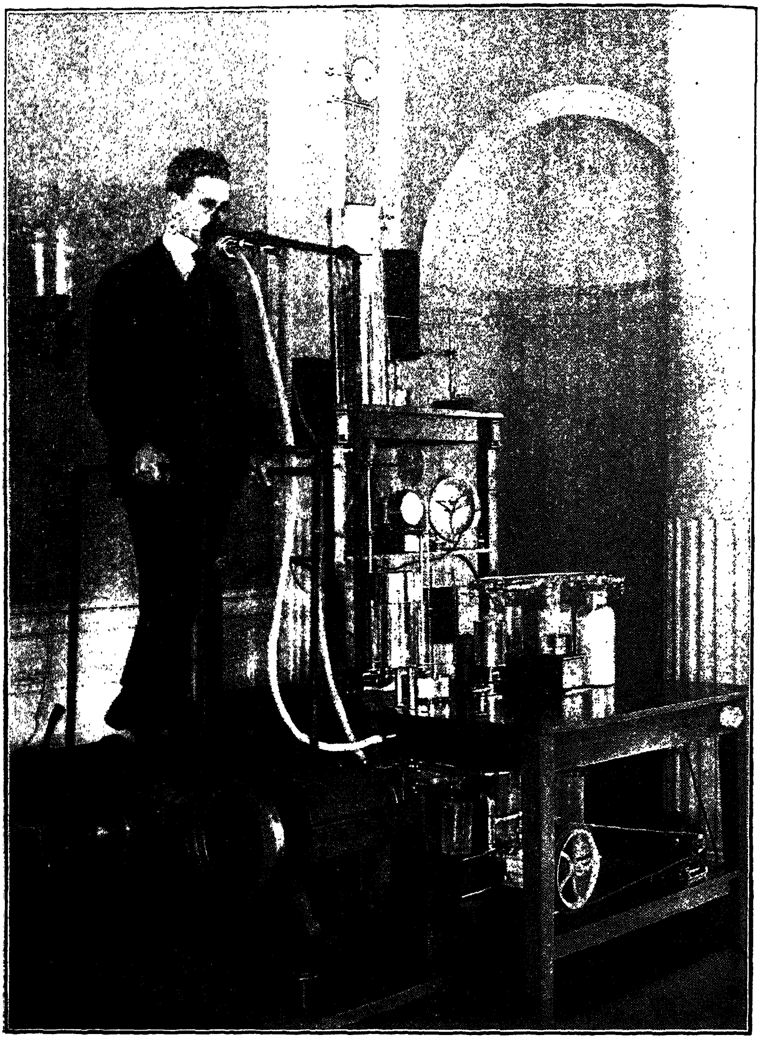

FIG. 12. Apparatus for the study of energy metabolism in walking. In this and in the types of apparatus shown in Figs. 13 and 14, the heat production is not measured directly, but the energy metabolism is computed from observations on the respiration, usually of the amount of oxygen consumed. The external muscular work which the subject here performs in walking is measured mechanically. (*Courtesy of Dr. F. G. Benedict.*)

of such experiments it was found that the energy metabolism computed from the data of the respiratory exchange and that measured directly as heat (or as heat plus external muscular work) agreed within a small fraction of one per cent. This finding resulted in general acceptance of the view that energy metabolism may be measured either by direct calorimetry (the man living in a calorimeter) or by the "indirect calorimetry" of computation from the chemically determined data of the respiratory exchange.

As a further development justified by this finding, there have also been devised several forms of simplified respiration apparatus (Figs. 12-14) which while measuring the energy metabolism do so without the need of such elaborate procedures. Thus it has now become practicable to measure the rate of energy metabolism of students in the classroom, patients in the clinic, and representatives of different races as encountered by field anthropologists in various parts of the world. These recently developed outfits, so much more portable and less expensive than those previously available, are also adaptable to the measurement of the energy metabolism of people of widely varied ages and occupations. Hence the somewhat wide-ranging discussions of this and the following chapter can be based almost entirely upon quantitative measurements of actual cases, and usually of many cases of a kind.

Basal Energy Metabolism

The basal energy metabolism (or basal metabolic rate) is a term often applied to the rate of expenditure of energy by a person awake, lying still, and who has taken little if any food during the past twelve or fourteen hours so that little digestion or absorption of food material is taking place at the time of observation (*i.e.*, in the "post-absorptive" state). This is often measured as a step in diagnosis in modern medicine.

In healthy grown people this basal energy metabolism averages just about one Calorie per kilogram of body weight per hour. This is supposedly the minimal rate of expenditure

of the normal man or woman when awake. During sleep the energy output is less, but when sitting erect it is more, while standing involves a still further expenditure of energy. A normal man, therefore, however sedentary he may be, is almost sure to expend in the course of the 24 hour day somewhat more than 24 times his *basal* hourly number of calories.

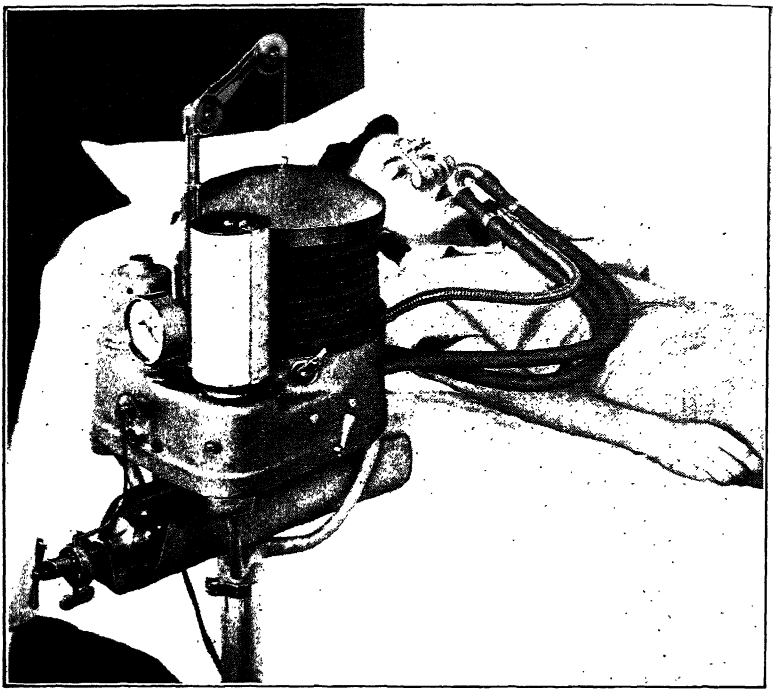

FIG. 13. A simple form of portable respiration apparatus. (*Courtesy of the Sanborn Company.*)

Moreover in any case the basal rate could be maintained throughout the day only by fasting. Eating is always followed by an increase in the rate of heat production, the extent of the increase depending upon both the character and the amount of food eaten, as explained below.

For a very full and expert account of the measurement and interpretation of the basal metabolism with special attention to its medical aspects, the reader is referred to DuBois' *Basal*

Metabolism in Health and Disease; and for a concise but liberally illustrated account, to Rose's *Foundations of Nutrition*. With such authoritative and up-to-date discussions so conveniently available, we here need merely mention any

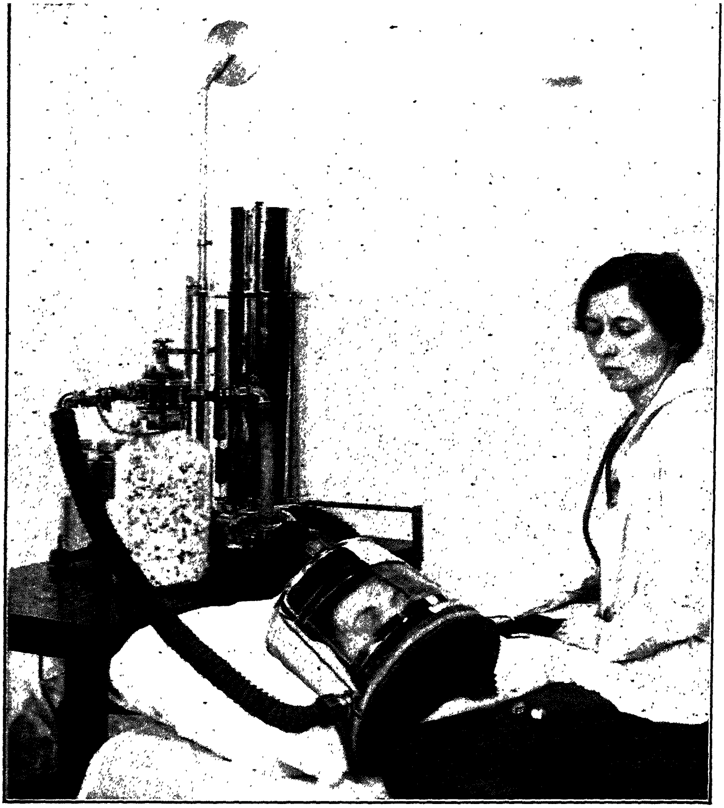

FIG. 14. The Benedict helmet form of respiration apparatus. (*Courtesy of Drs. F. G. Benedict and T. M. Carpenter.*)

of the factors affecting the basal metabolism which are not themselves essentially nutritional. We do not here enter at all upon the discussion of pathological conditions; and the somewhat vexed question as to whether there is "a racial factor" need be mentioned only so far as to point out that if a truly racial factor exists it must be a vanishingly small

one, when its very existence is still a subject of debate after such long and widespread investigation.

Benedict has concluded that the basal metabolism of an individual may be considered as quantitatively determined by: (1) the total mass of active protoplasmic tissue; and (2) the total stimulus to cellular activity existing at the time the measurement of the metabolism was made. Age, under such a generalization, becomes one of the factors causing variations in the stimulus to cellular activity.

The difference between boys and girls, in their basal energy metabolism per unit of weight or surface, is small in the early years but considerable in their teens; after which the difference diminishes to something like six per cent as between women and men, the latter having the higher rate.

Body Weight, Surface Area, and Energy Metabolism

Although loss of heat from the surface of the body is usually rather an end-result than a cause of energy metabolism, yet measurement seemed several years ago to have established empirically that energy metabolism is quantitatively more nearly proportional to body surface than to body weight. Much use has been made of the "surface area relationship" and some authorities treat it as more systematic to express measurements of energy metabolism in terms of Calories per square meter of body surface, than per kilogram of body weight. On the other hand the recently completed extensive studies of Benedict* left him skeptical as to the soundness of much of the supposed basis for considering surface area more significant than weight.

Inasmuch as among normal grown people the ratios between their weights and the ratios between their surfaces are not very different, and since any comparison of children with adults requires consideration of the age factor anyway, we have arranged the present text so that data presented either in terms of surface or of weight may be used without the necessity of converting one into the other.

*Benedict, F. G., "Vital Energetics." Publication No. 503 of the Carnegie Institution of Washington, 1938.

What Determines the Rate of Energy Metabolism in a Given Normal Individual at Rest?

While there is a never-ceasing exchange or transformation or metabolism of energy in every living body, the *rate* of this energy metabolism is not constant. It differs between individuals, and in the same individual from time to time.

There is, as yet, no neat, simple, comprehensive answer to the question, what determines the rate of energy metabolism; but several factors have been studied quantitatively, so that we have well-established information as to which are of major, and which of relatively minor, influence.

Thus to speak of two everyday, voluntary factors we may say that for all ordinary conditions the amount of exercise that one takes has more influence in determining the rate of energy metabolism than does the amount of food one takes. A healthy person living with a minimum of muscular activity and eating enough food for maintenance may be metabolizing, say, 1600 to 2000 Calories per 24 hours. This rate of energy metabolism per day can easily be increased one hundred per cent by exercise, while to double the food intake will not increase the 24-hour energy metabolism by more than about ten or fifteen per cent.

But while the food intake is not a major influence in determining the rate of energy exchange in the body, still it has a measurable effect; and it is not the same for the different groups of foodstuffs, nor proportional to their fuel values. In other words food intake does act appreciably to increase the rate of energy metabolism, and this "dynamic" action is "specifically" greater for some of the organic foodstuffs than for others.

Specific dynamic action of the foodstuffs.—In the quantitative study of this relationship, by Rubner and by Lusk independently, it was found that when enough food-calories for maintenance were fed, in the form of a single foodstuff at a time, the 24-hour metabolism was increased over that of fasting: 6 to 7 per cent by carbohydrate; 4 to 14 per cent by

fat; 30 to 40 per cent by protein. Another way of expressing these same experimental observations is to say that less than one-tenth of the energy value of the carbohydrate of the food, probably about one-tenth of the energy value of the fat, and about one-third of the energy value of the protein spends itself in its specific dynamic effect of increasing the rate of energy metabolism of the body as a whole and for the 24-hour day as a whole. In some experiments fat has shown a higher and in others a lower effect than carbohydrate, and the number of quantitative comparisons has not been large enough to justify statistical interpretation. What is really "specific" is the higher "dynamic effect" or output of "waste heat" which results from protein as compared with either fat or carbohydrate. A large amount of investigation and discussion has been devoted to this specific dynamic action of proteins and of their individual amino acids without any very clear-cut or scientifically significant outcome as yet. The practical significance thus far apparent is that protein is relatively less efficient and more heating as fuel for either the internal or external activities of the body than is carbohydrate or fat. This greater production of heat in proportion as protein is more largely used as fuel may be a source of comfort when one is exposed to severe cold, or of discomfort in hot weather; but usually it is not of great importance, because protein constitutes only about a tenth of the food-fuel of a normally-balanced diet. The exceptionally accurate measurements of Atwater and Benedict showed only 9 per cent of the total food calories expended in the "dynamic action" of the body's direct response to the intake of a mixed diet.

The influence of the habitual level of food intake.—Aside from the immediate specific dynamic effects of the foodstuffs, to what extent does the habitual general level of intake of food calories influence the habitual rate of energy metabolism?

Benedict and his coworkers, studying a group of 12 healthy young men who voluntarily accepted much-reduced

rations during the World War, found that when such undernutrition had reduced the body weight by 12 per cent it had reduced the rate of energy metabolism of the body at rest by 18 per cent. Whether this was an advantageous economy is doubtful. The men remained healthy and able to do their accustomed work, but there appeared to be some lowering of spontaneous vitality.

There are also well authenticated cases of underweight with relatively high energy metabolism which are interpretable in terms of simple absence of adipose tissue and consequent higher percentage of metabolically active lean tissue in the body, as in the lean school children found by Blunt to have rates of energy metabolism *per kilogram of body weight* from 16 to 24 per cent higher than children of average fatness. That in this case the measured difference in metabolic rate seems somewhat larger than the probable difference in body composition would account for, is easily explainable by the probability of higher muscular tone and perhaps greater thyroid activity in the thinner children. We shall return to the discussion of the thyroid in the chapter on iodine.

Talbot, also, has shown that undernutrition may result in either an increase or a decrease of the basal metabolic rate, according to circumstances.*

Regulation of Body Temperature

As warm-blooded animals we have evolved life processes which depend upon the maintenance of a fairly constant body temperature, and this is above that of our ordinary surroundings. To what extent, then, is the energy aspect of our metabolism a *direct* expenditure for the mere purpose of keeping the body warm? Certainly much less than is often supposed.

When we are comfortably clothed and housed, our body temperature is maintained, chiefly or wholly, by the heat

*Talbot, F. B. 1938 Basal metabolism of undernourished girls. *Am. J. Diseases of Children* 56, 61–66.

which is produced as a by-product of the work which the life processes involve anyway. And the heat-regulating center in the brain, acting through the nervous and circulatory systems, is able to conserve this resource by constricting the arterioles in the skin and thus diminishing the heat-loss from the surface. This is called *physical regulation*, while an increase of oxidation (burning of fuel foodstuffs) for the direct purpose of producing heat as such to keep up body temperature is called its *chemical regulation*.

For most of us in ordinary daily life, our physical regulation suffices; only at about the point at which we feel uncomfortably chilly, or at which shivering begins, is the chemical regulation (burning merely for heat) called into play. In fact it appears significant of the body's habitual dependence upon physical regulation that when increased oxidation is needed to maintain temperature the mechanism of muscle activity is still employed, namely, shivering as an involuntary form of muscular work whose function is merely to increase heat production.

The fact that physical regulation very nearly suffices for most of us during most of the time does not mean that the burning of foodstuffs for heat remains at complete zero, for anyone. And such use of food energy value for body heat may be a larger factor in children whose muscles are not yet fully developed, and in the aged whose muscle-tone is declining, than in robust young adults. Extreme thinness also may so increase the loss of heat from the body surface as to increase the calorie requirement.

Here as elsewhere the study of nutrition calls for a judicially balanced habit of thought. Need of heat as such for the maintenance of body temperature may at some times and for some people be a real factor in the energy requirement; but the body is not a heat engine, it usually gets enough heat in the course of doing its work, and one should not be misled by the fact that for convenience we count energy values in terms of calories.

Energy Values of Foods in Relation to the Metabolism of Energy in the Body

We saw in the last chapter that carbohydrates, fats, and the non-nitrogenous cleavage products of proteins all serve as fuel in the body. We know also that, throughout a very wide range (though not quite to an unlimited extent), the body can use these different fuel foodstuffs interchangeably in meeting its energy needs. And we have seen also how,

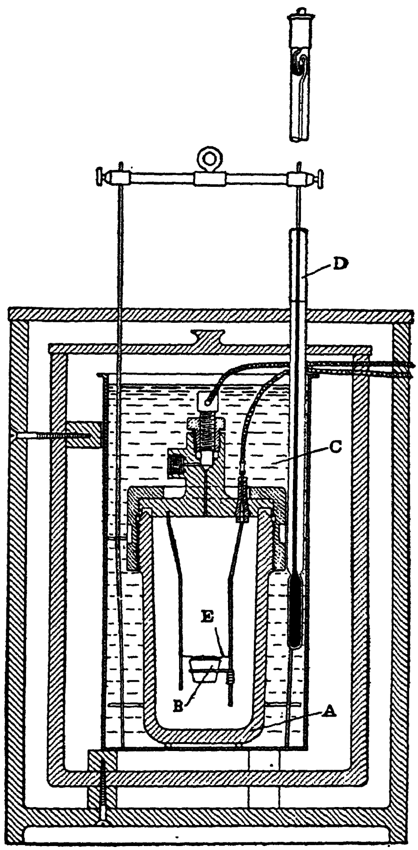

FIG. 15. The Atwater bomb calorimeter for determining the energy values (heats of combustion) of foods. It consists essentially of a heavy steel bomb, A, with a platinum or gold-plated copper lining and a cover held tightly in place by means of a strong screw collar. A weighed amount of sample is placed in a capsule, B, within the bomb, which is then charged with oxygen to a pressure of at least 20 atmospheres, closed, and immersed in a weighed amount of water, C. The water is constantly stirred and its temperature determined at intervals by means of an extremely accurate and sensitive thermometer, D. The sample is ignited by means of an electric fuse, E, and, on account of the large amount of oxygen present, undergoes rapid and complete combustion. The heat liberated is communicated to the water in which the bomb is immersed, and the resulting rise in temperature is accurately determined. After appropriate corrections have been made for loss of heat by radiation, heat arising from accessory oxidations (the oxidation of the iron wire of the fuse, etc.), the number of Calories arising from the combustion of the sample is computed from the rise in temperature of the water surrounding the bomb and the heat capacity of the apparatus.

though the body is not a heat engine, yet the Calorie serves as a convenient unit for expression and comparison of food energy values and the body's energy requirements.

The energy values of many pure foodstuffs have been determined by burning weighed specimens in compressed oxygen in calorimeters so arranged as to permit the energy liberated to be very accurately measured as heat (see Fig. 15). Thus one gram of pure dry starch yields 4.22 Calories, one gram of pure cane sugar, 3.96 Calories.

Averaging the results for each group of foodstuffs, correcting in all cases for average losses in digestion, and in the case of protein correcting further for the fact that oxidation in the body is less complete than in burning with oxygen, we obtain the following physiological fuel values:

Carbohydrate	4.0	Calories	per	gram	or	1814	Calories	per	lb.
Fat.........	9.0	"	"	"	"	4082	"	"	"
Protein......	4.0	"	"	"	"	1814	"	"	"

It is worthwhile to remember that the values 4.0, 9.0, and 4.0 were *not* obtained by "rounding off" the German estimates of 4.1, 9.3, and 4.1. The German experiments were with dogs fed upon diets which yielded less than average amounts of intestinal residue. The Atwater and Bryant averages of 4.0, 9.0, and 4.0, based upon larger numbers of experiments, made with men, and in which the diets were much more representative of normal human food supplies, are therefore the more accurate of the two sets of factors. Repeated reinvestigation and critical scrutiny has brought no significant modification of these as the most accurate *average* factors for use in the calculations of human food values and nutritional needs. (That the most accurate are also the most convenient is only an incidental advantage, not the reason for their adoption and continued use.)

In most cases it is customary to treat all nitrogenous matter involved in human dietary calculations as if it were protein. Only insignificant errors are ordinarily involved in this simplifying assumption. Using the accepted fuel values for protein,

fat, and carbohydrate, respectively, one may readily compute the energy values corresponding to a given food analysis, whether of an individual specimen or an average of many specimens of a given kind. In Appendix C of this book there are given such average analyses and fuel or energy (calorie) values for a considerable number of typical foods. More extended tables of such data may be found in larger or more technical books on nutrition and in Government bulletins.

Remembering that food value is something more than a matter of calories alone, it is nevertheless worthwhile to learn to think in terms of calories and to become familiar with the relative fuel values of different types of food.

Since proteins and carbohydrates have the same average fuel value and the ash of food does not often constitute a large percentage of its weight, the striking differences in fuel values of foods are usually due to differences in water content or fat content or both.

Lettuce is so largely water that as much of it as one would eat may furnish fewer calories than the least amount of oil which one would eat with it as salad dressing.

Hundred-Calorie Portions

Another way of dealing with the fuel value of foods is to treat the amount of each food which furnishes 100 Calories as a Standard Portion.

100-Calorie portions of some typical articles of food weigh as follows:

Butter (nearly pure fat), about ½ ounce
Sugar (pure carbohydrate), about 1 ounce
Lean meat (essentially protein with three times its weight of water), about 3 to 4 ounces
Bread, about 1⅓ ounces
Any dry cereal, or flour, or meal, about 1 ounce
Milk, about 5 ounces (two-thirds of a glass)
Cheese, ⅘ ounce (about 1 inch cube)
Dry beans, 1 ounce

Potato, 5 ounces (one fair sized potato)
Banana, 5½ ounces, with skin (one average sized)
Apple, 7 ounces, whole (one good sized apple)
Orange, 9-10 ounces (one large, or two small)
Prunes, dry, whole, 1⅛ ounces (four average sized prunes).

Large numbers of other examples, including many of cooked foods and "made dishes," may be found in Rose's *Laboratory Handbook for Dietetics*, 4th Ed. (1937) and in both the text and the Appendix of her *Feeding the Family*, 4th Ed. (1940).

EXERCISES

1. (*a*) How many Calories did each of your recorded dietaries (daily food intakes) furnish?

(*b*) What was the percentage distribution of each day's total Calories, as between protein, fat, and carbohydrate?

(The use of Rose's *Laboratory Handbook for Dietetics*, 4th Ed., 1937 (Macmillan) may greatly facilitate these calculations.)

2. Choose from twelve to forty foods* and (*a*) compute for each the percentage distribution of its Calories as between protein, fat, and carbohydrate, (*b*) arrange them in three lists in the order of the relative prominence of protein, fat, and carbohydrate, respectively (as thus computed with reference to distribution of the calories).

3. What is the total calorie value for each of your forty foods, per 100 grams of edible portion?

SUGGESTED READINGS

Benedict, F. G. 1928 Basal metabolism: The modern measure of vital activity. *The Scientific Monthly* 27, 5-27.

Chaney, M. S., and M. Ahlborn 1939 *Nutrition*, Revised Ed., Chapters II-IV. (Houghton Mifflin.)

DuBois, E. F. 1936 *Basal Metabolism in Health and Disease*, 3rd Ed. (Lea and Febiger.)

Rose, M. S. 1938 *Foundations of Nutrition*, 3rd Ed., Chapters II-IV. (Macmillan.)

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*This Exercise and the similar ones suggested at the ends of some of the subsequent chapters are intended to develop familiarity with the relative values of different foods as sources of different nutritive factors. It is suggested that your selection of foods include at least one from each of the twelve groups shown in Appendix F, and preferably several from some of the groups.

Rose, M. S. 1937 *Laboratory Handbook for Dietetics*, 4th Ed. (Macmillan.)

Rose, M. S. 1940 "Fuel for the human machine," "Sources of body fuel," "Measurement of the fuel value of food," and "Measurement of the fuel requirements of the body," in Chapter I of *Feeding the Family*, 4th Ed. (Macmillan.)

Chapter V

HOW TO MEET THE ENERGY NEED AND HAVE THE BODY WEIGHT YOU WANT

As explained in the preceding chapter, we and other living things "trade" in energy. It is chiefly because we see "expenditures" of energy, as in motion or in the giving off of heat to its surroundings, that we consider an object to be alive. Every living thing, then, is always "spending" energy, or, in more precisely scientific terms, is engaged in processes which involve transformations of energy. The total energy intake required to meet all these expenditures we commonly speak of as the energy need or energy requirement of the body. Having sketched the scientific foundations of this subject in Chapter IV, we now take up its everyday functioning.

Activity, age, and size are the outstanding factors in determining the amount of energy needed by a healthy person under ordinary conditions of life.

Mental and Muscular Activity as Factors in Energy Metabolism

Soon after the satisfactory development of their respiration calorimeter (noted in Chapter IV), Atwater and Benedict arranged to have 22 college students (separately) take mid-year examinations in this apparatus so that the energy metabolism while performing this mental work could be measured and compared with that shown by the same person for a parallel period at the same time of day, in the same physical posture and surroundings, but with no mental

work to do. There was no marked or constant difference in the results. Some students showed a slightly higher, and some a slightly lower, energy metabolism while taking the examination than in a period of equal length with parallel physical conditions without mental demand. If the mental work increased energy metabolism in the brain, the quantitative effect was so small as to be lost in the unavoidable fluctuations that occurred in the muscles. Even the brainiest person has many-fold more pounds of muscle than of brain, and spends many hundreds of Calories per day in muscular tension or tone. That some students spent more energy during their examination was probably mainly because their muscles as well as their minds were more tense during the ordeal than on the day of rest. And that some other students showed decreased energy expenditure during the examination-period was probably because they were so well-prepared and self-disciplined that the more they concentrated their minds upon the examination-questions the more completely their muscles relaxed.

The factor of muscular tension was probably more perfectly controlled in the later experiments of Dr. and Mrs. Benedict. In repeated experiments the Benedicts were able to demonstrate an increase of energy metabolism during periods of mental work. But the difference was so slight that they decided to make clear its smallness by reporting that the extra energy involved in an hour of mental work was no more than is furnished by half a peanut.

Thus the contrast between mental and muscular work is very pronounced, so far as its quantitative effect upon energy metabolism is concerned.

In the healthy adult, muscular activity is usually the largest variable factor in determining the rate of energy expenditure.

The average-sized man who spends about 100 Calories per hour when sitting still will (for the time being) approximately double this rate of expenditure if he simply strolls around the room, or treble it if he walks vigorously.

Moderate use of large muscles may easily involve a greater expenditure of energy than does the most intense use of a set of much smaller muscles. Thus the slowest walking will probably involve a larger output of calories per hour than the fastest typewriting.

Typical findings of energy metabolism per hour in healthy grown people differently occupied are shown in Table 1 (by courtesy of Dr. M. S. Rose).

Total Energy Requirement of Adults

By the use of such data as those in the accompanying table, the probable food requirement for a person of 70 kilograms (154 pounds) may be calculated very simply, as, for instance, in the following example:

8 hours of sleep at 65 Calories	=520 Calories
2 hours' light exercise* at 170 Calories	=340 Calories
8 hours' carpentry work at 240 Calories	=1920 Calories
6 hours' sitting at rest at 100 Calories	= 600 Calories
Total food requirement for the carpenter, per day,	3380 Calories

It may be of interest at this point to make a similar calculation for one's own case, and compare the outcome with the estimates for typical occupations below.

For a healthy grown person of normal physique but materially larger or smaller than 154 pounds (70 kilograms) weight, similar calculations can be based upon the data in the per-kilogram or per-pound columns of Table 1. Among such people, at least, the differences between their relative weights and their relative surface areas are not so large as to demand the figuring of the data to a surface-area basis.

Neither is it necessary for everyday purposes to make any further difference in energy allowances for men and for women than simply to credit each with his or her actual bodily size and occupation.

*Going to and from work, for example.

TABLE 1.—ENERGY EXPENDITURE PER HOUR UNDER DIFFERENT CONDITIONS OF MUSCULAR ACTIVITY

Form of Activity	Calories per Hour		
	Per 70 Kilograms	Per Kilogram	Per Pound
Sleeping	65	0.93	0.43
Awake lying still	77	.10	0.50
Sitting at rest	100	.43	0.65
Reading aloud	105	.50	0.69
Standing relaxed	105	.50	0.69
Hand sewing	111	.59	0.72
Standing at attention	115	.63	0.74
Knitting	116	.66	0.75
Dressing and undressing	118	.69	0.77
Singing	122	1.74	0.79
Driving automobile	133	1.90	0.86
Typewriting rapidly	140	2.00	0.91
Dishwashing	144	2.06	0.93
Ironing	144	2.06	0.93
Laundry, light	161	2.30	1.04
Sweeping	169	2.41	1.09
Walking, 2.6 miles per hour	200	2.86	1.30
Carpentry, metal working, industrial painting	240	3.43	56
Bicycling, moderate speed	245	3.50	59
Dancing, waltz	280	4.00	82
Walking, 3.75 miles per hour	300	4.28	95
Dancing, foxtrot	336	4.80	2.18
Walking down stairs	364	5.20	2.36
Horseback riding, trot	371	5.30	40
Sawing wood	480	6.86	12
Swimming	500	7.14	25
Running, 5.3 miles per hour	570	8.14	70
Walking, 5.3 miles per hour	650	9.28	22
Walking up stairs	1100	15.8	7.18
Rowing in race	1190	17.0	7.65

The following are typical expert estimates of the energy need of the 24-hour day:

Lusk estimated that,—

A seamstress sewing with a needle required 1800 Calories;

Two seamstresses, using a sewing machine, required 1900 and 2100 Calories, respectively;

Two bookbinders required 1900 and 2100 Calories;

Two household servants, employed in such occupations as cleaning windows and floors, scouring knives, forks, and spoons, scouring copper and iron pots, required 2300 to 2900 Calories;

Two washerwomen, the same servants as the last named, required 2600 and 3400 Calories in the fulfillment of their daily work.

According to Tigerstedt,—

2000-2400 Calories per day suffice for a shoemaker;
2400-2700 Calories per day suffice for a weaver;
2700-3200 Calories per day suffice for a carpenter or mason;
3200-4100 Calories per day suffice for a farm laborer;
4100-5000 Calories per day suffice for an excavator;
Over 5000 Calories per day are required by a lumberman.

It is of course to be kept in mind that only the well-muscled and well-trained person is in position to transform as much energy in a day as does an excavator, a longshoreman, or a lumberman. The most active exercise that a man of sedentary occupation would be apt to take for pleasure, even in competitive sports, would probably put him in the 3000-4000 Calorie per day class.

While the more technical books have much to say about the differences in energy requirements between men and women, partly on the ground of studies of basal metabolism and partly because of the relatively great demands of heavy muscular work, it is worth while on the other hand to say that a large proportion of both men and women have energy needs not far from a range of about 2200 to 2800 Calories per day. Women take more exercise than formerly, are often less sedentary than the men working in the

same offices, and many do housework in addition to the duties of full-time employment outside of the home. Meanwhile it is a steadily decreasing proportion of men who are engaged in heavy physical toil, and this trend will doubtless continue with the increasing use of labor-saving machinery in all kinds of occupations.

Worry, anxiety, nervous strain, may increase muscular tension and decrease the efficiency of muscular work, both of which effects would tend to increase energy requirement. But (as we saw in Chapter IV) one's *feeling of fatigue* may bear but little relation to the number of calories spent. One may be greatly fatigued by a day of either hand- or type-writing; but it may not involve as much energy expenditure as a day of recreation.

For guidance in the practical planning of food to meet the needs of people of different ages and types, and at different cost levels, Rose's *Feeding the Family* is especially recommended.

Exercises in the planning and evaluation of dietaries from the viewpoints of different aspects of nutrition are suggested at the ends of several of the chapters of the present book. If at this stage you are undertaking an exercise in which only the calories of the diet are specified, it is nevertheless well to realize even from the start that every dietary should be well-balanced with respect to other nutritional essentials also.

Closely connected with the question of the calories-per-day called for by one's size and occupation, is the question of the control of body weight.

Food Calories and the Control of Body Weight

While the body's weight may sometimes be significantly influenced by its water balance, in the vast majority of cases over-weight means over-fatness.

We have seen that surplus calories of ingested food, whether taken in the form of protein, fat, or carbohydrate, tend to accumulate in the form of body fat. And over-fatness

always means that the intake of food calories has been out of proportion to the expenditure of energy *by the person concerned.* Undoubtedly there is more tendency to overweight in some people than in others, and undoubtedly, too, this sometimes extends beyond the question of appetite to endocrine and perhaps other constitutional differences; yet the fact remains that *for the individual* the control of body weight is essentially a matter of a proper balance between what is ingested as food and what is oxidized in the energy metabolism. If one tends to become too fat, the remedy is to eat less or to burn more, or both.

To increase basal metabolism by administration of thyroid, thyroxine, or any artificial drug designed to increase oxidation is too dangerous for any except very rare cases under strict medical control.

To increase the energy metabolism by muscular exercise is probably beneficial in a fair proportion of cases but is apt to be an arduous process of weight reduction, especially as exercise usually increases the appetite. Moreover, increased muscular exercise in the obese may endanger the heart. So it is often comforting to remember the principle expounded by M. S. Rose that "the only form of exercise essential to the control of body weight is the exercise of the intelligence."

The scientific attitude does not simply ask, Is this food fattening?, nor even simply, How fattening is it?, but *both* How does it stand as a source of calories? *and* How important is it as a source of protein and of the needed mineral elements and vitamins? If a slogan must be carried in mind, perhaps, "No calories without vitamins," is as good a precept as any.

Almost always the desirable degree of reduction of calorie intake can be made among the foods that are not important sources of mineral elements and vitamins, and it is among such foods that the "cutting out" or the "cutting down" should be done.

One should not proceed too drastically, nor should one be discouraged or confused by short-time fluctuations of body weight. Not only may the body gain or lose a few pounds of

water without apparent reason or effect upon health, but also the fluctuations in the body's glycogen content influence its water content at the same time, each gram of glycogen being usually accompanied by about three grams of water. Thus 400 Calories gained or spent in the form of 100 grams of glycogen may quickly change the body weight about 400 grams, while the gain or loss of this weight of fat would involve about 3600 Calories.

Keeping in mind therefore that sudden fluctuations of a few pounds do not call for any change of plan, and that any weight-reduction plan should aim not at rapidly spectacular results but at steady moderate progress, it is well to deduct about 500 Calories from the daily intake which would presumably keep the body weight constant.

A withdrawal from bodily stores of 500 Calories per day or 3500 Calories per week will normally mean the burning-off of about 380 grams of actual fat. And this will mean a reduction of body weight by about one pound of adipose tissue; for adipose tissue is about four-fifths actual fat and about one-fifth water. Thus the daily deficit of 500 Calories reduces body weight about one pound per week, and this is about as rapid a reduction as one should attempt unless under constant medical advice and observation.

To what extent is the body weight a health problem, and to what extent is it merely a question of style? The evidence seems indubitable that a large proportion of young women do keep themselves thinner than is best for health, happiness, efficiency, and longevity.

Those whose body weight is below that shown by the standard average tables for their height and for the age of thirty years, will generally be wise to build up their weight to this standard. Extreme thinness is a real hazard, and one which very few people need incur. The rational cultivation of a good appetite usually requires only a little intelligence, and well rewards it. As Professor Mary S. Rose has emphasized, underweight college women commonly regard themselves as well, and then are surprised to find how

much better they feel, and how much less subject to fatigue, when they begin to gain weight.

A moderate store of body fat is a real asset, and not simply as stored fuel. As briefly noted above, the two chief regions of storage fat are (1) within the abdominal cavity, and (2) directly beneath the skin. In both of these locations it performs important functions. The intra-abdominal fat serves as packing and support for the kidneys, and doubtless to some extent for other vital organs as well. Socalled floating kidney is largely due to the lack of a sufficient normal "packing" of fat around the organ to give it proper support and keep it steady in its place. The usefulness of the subcutaneous fat is at least two-fold. It protects the muscles from bruises, and it tends to protect the body as a whole from the effects of sudden changes in the temperature of its surroundings, and to aid in conserving body heat against a cold environment even for a longer time. Thus a moderate amount of body fat is an important part of one's protection against the chilling of the vital organs—and such chilling means not only discomfort, it means also increased danger of disease.

Underweight, therefore, especially in young people, is a condition calling for remedy; and the remedy is, of course, nutritional. Calorie intake should be increased, gradually but systematically, until there is built up a sufficient store of body fat to bring the weight to the standard for the height and for age 30. (See accompanying Table 2 based on data published by the United States Public Health Service. Note that in this table the height includes ordinary shoe-heels and weight includes ordinary indoor clothing.)

In cases in which either lack of appetite or a subnormal digestive capacity makes the taking and digesting of sufficient food a real problem, attention should be given to such selection of food and arrangement of meals as to stimulate the appetite and avoid overburdening the digestive apparatus, and care should also be taken that there is sufficient out-door life, and sufficient ventilation indoors, to develop

TABLE 2.—WEIGHT FOR HEIGHT AS OF AGE 30

HEIGHT	WOMEN	MEN
4 ft. 8 in.	112	
4 ft. 9 in.	114	
4 ft. 10 in.	116	
4 ft. 11 in.	118	
5 ft. 0 in.	120	126
5 ft. 1 in.	122	128
5 ft. 2 in.	124	130
5 ft. 3 in.	127	133
5 ft. 4 in.	131	136
5 ft. 5 in.	134	140
5 ft. 6 in.	138	144
5 ft. 7 in.	142	148
5 ft. 8 in.	146	152
5 ft. 9 in.	150	156
5 ft. 10 in.	154	161
5 ft. 11 in.	157	166
6 ft. 0 in.	161	172
6 ft. 1 in.		178
6 ft. 2 in.		184
6 ft. 3 in.		190
6 ft. 4 in.		196
6 ft. 5 in.		201

and support a good appetite; that fatigue of any kind or at any time is avoided; that provision is made for complete rest before and after meals; and that the meals consist largely of fruits, vegetables, and milk as well as more concentrated foods.

The proper nutrition of an underweight person is only in part the reverse of the proper correction of overweight, because in both cases the calories in the food and the fat in the body while prominent in the problem do not tell the whole story. Such important protective foods as fruit and milk should be fairly prominent in both the fattening and the reducing types of diet. The late Dr. L. H. Peters particularly commended to those on reducing diets liberal servings of salad dressed with cheese and vinegar instead of any dressing made with oil.

The principle embodied in the preceding paragraph,—adjustment of food calories without sacrifice of natural food values,—is of very far-reaching importance, and its practical application is often almost absurdly simple. Thus one may eat a good-sized (thoroughly washed) raw apple with an intake of only about one hundred Calories and with all the mineral elements and vitamin values that such an apple brings; while a baked apple of the same size will probably have at least another hundred Calories of added sugar. So for one who wishes to reduce there is a large advantage in the raw apple. To a still greater extent is the apple "diluted with foreign calories" when it is eaten in the form of apple pie. A raw apple instead of an average piece of apple pie will mean *more* of actual apple (with all of its nutritional virtues) at the same time with a greatly reduced calorie intake. Probably every apple calorie in the pie is diluted with at least three or four foreign calories of sugar, flour, and fat. This principle of avoidance of culinarily-added calories need only be applied to a moderate proportion of the items in a day's food in order to effect a considerable change in the calorie intake while fully maintaining or even increasing the protein, mineral, and vitamin values. The interested student can readily set down in parallel columns two food plans for a day each having the same number of items and variety of flavors and essentially the same amounts of the protective foods of high mineral and vitamin value, but with widely different total calories according as the foods which "bring calories without vitamins" are used in larger or smaller amounts.

Obviously the present discussion relates only to the problem of relatively permanent adjustment of the body's energy intake and output, and not to spectacular dieting campaigns of a few days' duration. To attempt a critique of the latter would not be within the scope of this book. Also we shall not take space here for any more detailed consideration of the relation of body weight to general wellbeing, especially as

one of the present writers has discussed this in his book entitled *Food and Health.*

The little bulletin by Professor Harriet Barto on *Sane Reducing Diets and How to Plan Them** is excellently concise and scientifically sound; and in her book entitled *Feeding the Family* Dr. M. S. Rose includes full and careful accounts and discussions of feeding both for increase and for reduction of body weight.

Energy Needs During Physical Development

Investigations of young infants regularly show them to give off at least twice as much energy per unit of weight as their mothers do. This is partly explainable on the ground of size; for as between a baby and a grown person the ratio of surface to weight is very different, and, as energy metabolism is more nearly proportional to surface than to weight, the baby's larger surface per pound would of itself mean more calories per pound. Also, children soon begin to take active exercise. Their crying and kicking may add from 25 to 100 per cent to the 24-hour calorie requirement; and by the time this stage of their development is over, the run-about stage has begun. Most grown people would find their muscles overworked if they tried to repeat their children's physical activities. And thirdly, the child's food requirement is further accentuated by the fact that the intake must not only cover the output but provide also for the retention by the body of the food substances which become tissue material in the processes of growth.

In a more technical treatise on nutrition, or in a handbook of practical dietetics, there would here follow a more or less elaborate derivation of children's energy requirements or of the planning of meals to meet them, or both. For the more concise purpose of the present writing it is deemed sufficient to indicate the net results of investigations of the daily needs for energy at different ages in Table 3 and an

*Full reference under Suggested Readings.

expert recommendation of the proportions in which to draw the needed calories from the chief types of food at different ages in Table 4.

It should be carefully kept in mind that Table 4 is designed to serve the largest possible proportion of people and therefore concedes as much as practicable to the need for pecuniary economy as well as to custom. For this reason and also because of our steadily advancing knowledge, the ideal dietaries planned today may well use such "protective" foods as fruits and milk even more liberally.

Energy Metabolism in Middle-Aged and Elderly People

Emerson was sixty-three when he wrote with reference to his age, "It is time to take in sail." How shall we translate his poetic expression of physiological experience into terms of the energy metabolism?

First of all it should be emphasized that physically, and to an even greater extent mentally, people differ in their reactions to the passage of years. Some are younger at seventy than others are at sixty, and the difference while largely constitutional is also doubtless due in greater measure than previously believed, or yet generally appreciated, to the internal environment induced and maintained by one's daily choice of food.

But somewhere between the ages of fifty and seventy the energy metabolism may be expected to show significant diminution from the young-adult levels with which most of the preceding text has been concerned. Strictly speaking, the generally accepted normal standards for basal energy metabolism show a slight gradual diminution from the 'teens onward; but this is insignificant compared with the differences in total energy metabolism resulting from differing muscular activity. When, somewhere in middle or advancing age, the effect of diminishing muscular activity is added to that of the slow decline in basal metabolism, the result is a significant decrease in the number of food-calories

TABLE 3.—FOOD ALLOWANCES FOR CHILDREN OF ABOUT AVERAGE WEIGHT FOR THEIR AGE

(Based on Gillett's *Food Allowances for Healthy Children* and Rose's *Laboratory Handbook for Dietetics.*)

AGE Years	CALORIES PER DAY	
	Boys	Girls
1	900–1200	800–1200
2	1100–1300	1000–1250
3	1100–1400	1050–1350
4	1200–1500	1150–1450
5	1300–1600	1200–1500
6	1500–1900	1450–1800
7	1600–2100	1500–1900
8	1700–2300	1600–2200
9	1900–2500	1800–2500
10	2100–2700	1900–2600
11	2100–2800	2000–2800
12	2300–3000	2100–3000
13	2500–3500	2300–3400
14	2600–3800	2400–3000
15	2700–4000	2400–2800
16	2700–4000	2250–2800
17	2800–4000	2250–2800

TABLE 4.—PROPORTIONS IN WHICH TO DRAW THE NEEDED CALORIES FROM THE DIFFERENT TYPES OF FOOD, AS SUGGESTED BY M. S. ROSE (1940)

CLASS OF FOOD	PER CENT OF TOTAL CALORIES IN DIETARY OF CHILD, AGED:				
	1–2 Years	3–5 Years	6–7 Years	8–9 Years	10–12 Years
I. Food from cereal grains..	16	18–20	22	21	20
II. Milk..................	67.5	45–55	45	40	34
III. Vegetables and fruits.....	10	16–22	16	18	20
IV. Butter.................	3	4–8	10	12	14
V. Sugar and other sweets...	1	1–3	3	4	6
VI. Eggs, cheese, meat and other flesh foods.......	2.5	3.5	4	5	8

needed per day. Probably 1500 to 2000 Calories per day, depending upon size and musculature, will meet the energy needs of most people of seventy and over. Quantitative statements, however, can not be made with confidence because the relatively few cases which have been studied accurately and systematically show considerable individual differences, and there probably is and will be somewhat less average difference in activity between men of fifty and of seventy than in the past, as the occupations of middle life are less muscular and the grandfather of today and tomorrow may be expected to retain the activity of early middle age through a longer term of years.

EXERCISES

1. Compute your Calorie requirement per 24-hour day, from your body weight and the number of hours you spend in different activities.
2. Plan a day's dietary to meet your computed Calorie requirement, choosing the foods from among the forty with which you have familiarized yourself in the Exercises of the preceding Chapter.
3. How would you change the dietary planned in Exercise 2 to make it a reducing dietary with about 500 Calories less of total energy value?
4. A student 20 years old and 5 ft. 5 in. tall is underweight. Modify the dietary planned in Exercise 2 above so as to build up the body weight of this student. Is the "fattening" diet you have thus planned appetizing? Is it comfortably digested? Is it reasonably economical in cost?
5. How many Calories of food per day would you allow for a family consisting of a bookkeeper of 45 (weight 155 lbs.); wife of 40 (weight 125 lbs.) who does all of the housework; a girl of 15, a boy of 13, and a boy of 11, all of average size for their ages and all attending school?

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Chapter VI

HOW TO MEET THE NEED FOR PROTEIN

Proteins are the principal organic constituents of the active tissues of the body, and since the body can form these indispensable substances only from the digestion-products of food proteins, the "protein problem" has been and is of outstanding interest to students of nutrition.

Nutritional Functions of the Dietary Protein

As we saw in Chapter III, the large, complex protein molecule is resolved (hydrolyzed, "broken down") by the digestive processes essentially to amino acids, the simple units of which it is composed.

Every protein yields on hydrolysis at least several different kinds of amino acids; and not less than twenty-one amino acids are now recognized as commonly received by the body from its protein food. The names of these twenty-one are as follows: glycine (glycocoll), alanine, valine, leucine, isoleucine, norleucine, phenylalanine, tyrosine, serine, threonine, cystine, methionine, aspartic acid, glutamic (glutaminic) acid, hydroxyglutamic acid, arginine, lysine, histidine, proline, hydroxyproline, and tryptophane. The chemical names and structural formulae of these amino acids are given in Chapter IV of Sherman's *Chemistry of Food and Nutrition*.

It is essentially in the form of amino acids that food proteins are absorbed from the intestinal tract and carried to the tissues where they are used. Indeed, W. C. Rose of the University of Illinois has demonstrated that a suitable mixture of amino acids is a nutritionally satisfactory substitute

for protein even in the diet of young, growing experimental animals. He has shown also that if any one of ten socalled "nutritionally essential" amino acids is lacking in the amino-acid mixture, normal growth will not occur. But if all ten of these are provided in suitable amounts, the body can form from them the remaining amino acids which enter into the composition of its proteins. The ten amino acids now called "nutritionally essential," in the sense that they must be furnished through the nutriment, are:

Arginine	Methionine
Histidine	Phenylalanine
Isoleucine	Threonine
Leucine	Tryptophane
Lysine	Valine

From the amino acids which the blood distributes, the organs and tissues synthesize the numerous body proteins upon which depend so many aspects of the life process. For, not only are proteins essential components of all protoplasm, and the most abundant constituents of the active tissues; they and their derivatives have other highly significant functions. Many of the enzymes and other catalysts which the body makes, it makes either wholly or in part from the digestion-products of the food proteins. Moreover the hemoglobin in the red blood cells, which transports oxygen from the lungs to the tissues where it is needed, is a protein. And, throughout the body, proteins in solution play an essential part in maintaining neutrality and in controlling the distribution and exchanges of the body water.

In addition to their use for the synthesis of proteins, some of the amino acids go into the formation of less complex substances, such as glutathione (which contains the amino acids glycine, cystine, and glutamic acid); and the hormones epinephrine ("adrenaline") and thyroxine (which are related to the amino acid tyrosine).

Secretin, which was mentioned in Chapter III as the hormone which serves as the "messenger" from the stomach to the pancreas in digestion, has also been found to be an amino-

acid derivative. It is classed as a polypeptide, being intermediate in molecular size between such a chemically simple hormone as thyroxine, and, on the other hand, such typically protein substances as pepsin and trypsin.

The amino acids in excess of those required for the specific functions of the building or repair of body proteins or the formation of other nitrogenous metabolites, are deaminized (lose their amino groups) and the remaining fragments are burned to yield energy or converted into body fat. But, since we know that carbohydrate and fat may fully meet the body's energy requirement, this is not to be regarded as a specific function of the dietary protein in the same sense as those functions discussed in the preceding paragraphs.

Factors Determining the Nutritive Value of Proteins

It has long been recognized that all proteins are not of the same value in nutrition. Thus, in 1872 Voit found that the protein gelatin could not be substituted for meat protein in the diet of dogs without the loss of body protein. Later, Osborne and Mendel, in some of the early work using rats as tools* for nutrition research, compared the nutritive effectiveness of a number of purified proteins (Fig. 16). They found, for example, that when the only protein in the diet of young rats is casein the animals are able to grow normally. While if gliadin, one of the proteins of wheat, is given in place of casein the animals, although they maintain their body weight (and stores of protein), grow little or not at all. If, however, zein, *one* of the proteins of corn (maize), is the only protein fed, the animals lose weight and die. When tryptophane, an amino acid not present in zein, but found in casein and in gliadin (and also in maize proteins other than zein), is given in addition to zein, rats may be able to maintain their body weight although they cannot grow. But if lysine, another amino acid which zein lacks, is further given

*The experimental animal is only a tool or instrument of research when the problems are those of human nutrition; but it may be well to emphasize at this point the fact that the chemistry of the protein metabolism has been studied in considerable detail and found to be strikingly parallel in human and rat nutrition.

in addition to the protein zein and the amino acid tryptophane, the rats are enabled to gain weight rapidly (See Fig. 17).

Correspondingly, an explanation of the fact that gliadin as sole protein in the diet suffices for maintenance but cannot promote normal growth is suggested by the finding that

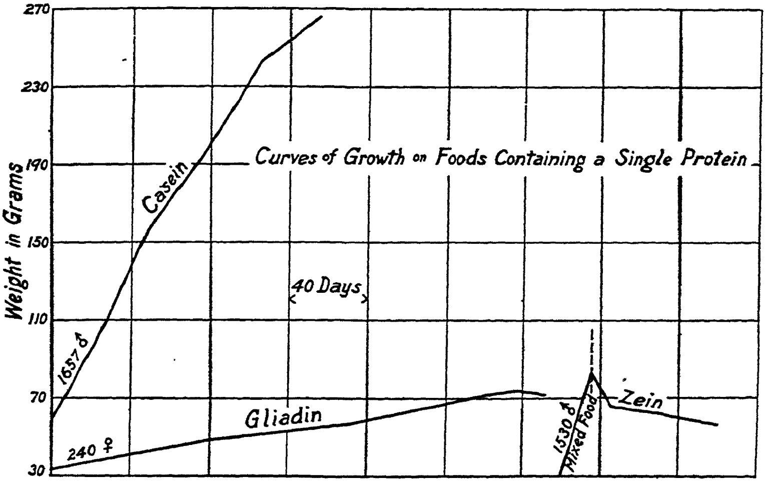

FIG. 16. Effect of the kind of protein in the diet on the rate of growth. Body weight curves of typical rats on diets otherwise similar and adequate but containing in each case only a single protein, casein, gliadin, or zein, fed at the same liberal level, 18 per cent of the food mixture. (From the experiments of Osborne and Mendel.)

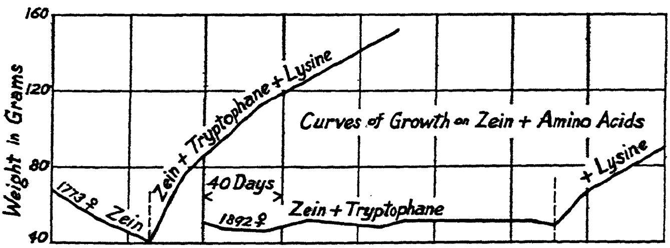

FIG. 17. Effect of adding to a diet containing zein as sole protein the amino acids lysine and tryptophane: showing that a "nutritionally incomplete" protein can support growth when supplemented by the essential amino acids which it lacks. (From the experiments of Osborne and Mendel.)

this protein contains only a very small quantity of the amino acid lysine. Osborne and Mendel observed actually that gliadin fed with supplementary amounts of lysine affords an amino-acid mixture fully satisfactory to meet the needs of a normal rate of gain in body weight.

These and many other instances in which chemical studies of the amino-acid composition of a protein were correlated with nutritional studies of its effectiveness in meeting the body's protein requirement have shown clearly that the nutritive value of a protein depends primarily upon the kinds and relative proportions of the amino acids into which it is resolved by digestion. (There are a few cases in which secondary factors may have some nutritional significance; but they are not of sufficient importance to warrant discussion here.)

More About Nutritionally Essential Amino Acids

Out of such studies grew also the concept that—while some twenty or more individual amino acids comprise the body proteins, each of which amino acids is in this sense essential to the body structure—only certain specific ones of these are *nutritionally essential* (*nutritionally indispensable*) in the sense that they must be supplied by the nutriment before the body can grow (form new protein) at a normal rate, whereas others need not be supplied by the food since they can be derived from other materials ordinarily available within the body. For instance, the amino acids glycine, tryptophane, and lysine are absent from the protein zein. As we have seen (Fig. 17), the feeding experiments with zein as sole dietary protein afford evidence in favor of classifying tryptophane and lysine as nutritionally indispensable, for growth occurs only when *both* of these amino acids are fed in addition to zein. Glycine, on the other hand, appears from this experiment to be nutritionally dispensable, inasmuch as a zein-lysine-tryptophane mixture which supplies no glycine can nevertheless satisfy the amino-acid requirements for normal growth.

However, there are not many instances where the nutritional indispensability of an amino acid can be tested so simply as that of the three just discussed. Known cases of *complete absence* of one or two amino acids from an otherwise satisfactory protein are comparatively rare; and, furthermore, the chemical methods for the detection of many of the amino acids are not extremely delicate, so that apparent lack of one of these amino acids from a protein under investigation might indicate simply that the amino acid is present in low concentration. For it is evident that, while it may be possible to show that a given amino acid *is* nutritionally essential without having excluded it altogether from the basal diet, one cannot conclude that a given amino acid *is not* nutritionally essential unless it can be established that normal growth is possible on a diet which is beyond doubt completely devoid of the amino acid in question. Otherwise the possibility remains that the organism does require a dietary supply of the amino acid but that the amounts needed are so small that they can be satisfied by the very low concentration afforded by the basal diet.

It has therefore been necessary to find other means for effectively excluding from the diet the amino acid whose status is under investigation, while supplying to the experimental animal all of the other factors required for normal nutrition. The attainment of this objective, and the resulting classification of the known amino acids as "nutritionally essential" or "nutritionally dispensable," is largely the result of many years devoted to this field of investigation by William C. Rose and his associates at the University of Illinois. These investigators put together mixtures of purified amino acids in the proportions in which they were supposed to occur in some nutritionally "complete" proteins; with the idea that such a mixture when introduced in place of protein into an otherwise suitable diet should permit normal growth, and that one might then proceed to investigate the nutritive importance of individual amino acids by omitting them, one by one, from the mixture and ascertaining the effect of this

change upon growth. Casein was chosen as a pattern to be followed in compounding such a mixture of amino acids; but it was soon found that all of the then known amino-acid components of this protein fed together in the appropriate proportions failed to support good growth, although, under otherwise identical conditions, casein itself gave excellent results. The search for an explanation of this observation led ultimately to the discovery of the amino acid *threonine* which had not hitherto been identified as a component of proteins. This discovery—in itself of the greatest scientific interest—solved the final difficulty in the way of preparing a synthetic mixture of purified amino acids which can fully meet the nutritional need for protein. Then, by successively excluding one or another amino acid, Rose was able to show that ten amino acids satisfy his definition of "an indispensable dietary component as one which cannot be synthesized by the animal organism, out of the materials *ordinarily available* at a speed commensurate with the demands for *normal* growth." These are the ten nutritionally indispensable or "nutritionally essential" amino acids listed above (p. 91).

Though it is true that the body can get along on a mixture of just these ten amino acids, it is not true that the nutritive value of a protein can be interpreted fully in terms of the amounts of these amino acids which it supplies. For the essential amino acids may be thought of as used in two distinct ways:

(1) *unchanged*, as building stones for body proteins, enzymes, etc., for which purpose, obviously, the particular indispensable amino acid and it alone may be used;

(2) *as precursors*, from which are formed the socalled dispensable amino acids.

It would seem logical to expect that the amounts of the indispensable amino acids which are required will be increased in proportion as the dispensable amino acids of which they are precursors are lacking in the food; and conversely, the need for them should be somewhat diminished if the diet provides liberal amounts of the socalled dispensable acids.

Whether or not this merits consideration from a practical point of view will depend upon how specific is the relationship between indispensable and dispensable amino acid. It is shown to be of great importance in the case of the sulfur-containing amino acids, methionine and cystine. According to the usual definition, methionine is characterized as indispensable, cystine as dispensable. Methionine, however, is the only known material ordinarily presented to the body from which cystine may be formed. Thus, of all the usual dietary constituents, methionine alone can fulfill the bodily functions for which methionine itself is required; and only methionine or cystine can supply the cystine needed for body processes. What, then, if a diet supplies a limited amount of methionine—enough, let us say, to meet the growth requirements for methionine *per se* but not sufficient to provide the needed cystine? Whether or not growth can occur under such circumstances will depend directly upon the amount of cystine which the diet supplies. In such a case, a socalled nutritionally dispensable amino acid may be the very factor upon which the nutritive value of the diet depends! This is illustrated, for example, by Osborne and Mendel's experiments with low-casein diets (Fig. 18).

How May the Nutritive Value of a Protein be Assessed?

Except for a few cases presenting abnormalities or particular difficulties in digestion, it is now believed that the nutritive values of the food proteins depend (as has already been intimated) essentially upon the kinds of amino-acid radicles which they contain and the quantitative proportion of each. As yet, however, methods for the detection and determination of the individual amino acids are still being perfected. Present knowledge is extensive and highly significant; but it is certain that many of the quantitative data are subject to improvement in precision. Furthermore, there is still a great deal to be learned about the relative proportions of the amino acids that are needed.

Hence, at the present time, we *interpret* nutritional differ-

ences among proteins essentially in terms of their amino-acid make-up; but it is not yet safe to *predict* quantitative differences in nutritive value on the sole basis of the data obtainable *in vitro*. Empirical determinations of nutritive values by means of quantitatively conducted feeding experiments

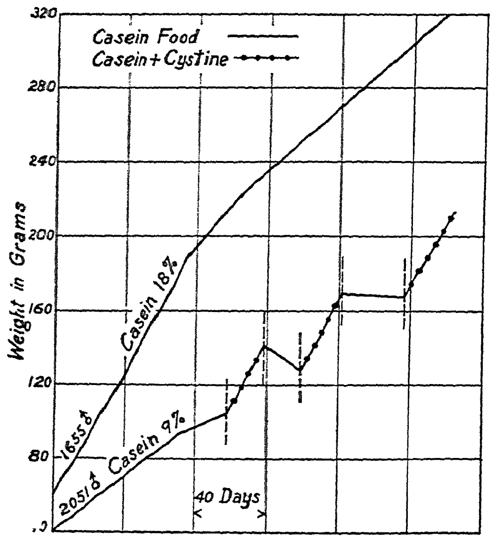

FIG. 18. Effect on growth of reducing the proportion of casein in the diet; and of feeding the amino acid cystine in addition to the lower level. This experiment of Osborne and Mendel illustrates the facts: (1) that a protein which at a liberal level of intake (here 18 per cent) supports a normal growth may be unable to do so when fed in reduced proportion (here 9 per cent); and (2) that, as explained in the text, under certain circumstances growth may be promoted by the addition of a so-called nutritionally dispensable amino acid (in this case cystine).

are still needed, as well as qualitative and quantitative investigations *in vitro* of the amino-acid make-up of the proteins concerned.

On the basis of tests, such as those of Osborne and Mendel already mentioned, in which young experimental animals are fed diets containing only a single, isolated protein, the follow-

ing qualitative classification of proteins has been suggested and considerably used in teaching:

(1) "Complete" proteins: those which maintain life and provide for normal growth of the young when used as the sole protein food. Casein is the example of a complete protein in the preceding discussion. Other proteins in this group include lactalbumin from milk; ovalbumin and ovovitellin of egg; glycinin of soybean; excelsin of Brazil nut; and edestin, glutenin, and maize glutelin of the cereal grains.

(2) "Partially incomplete" proteins: those which maintain life but do not support normal growth. From the work of Osborne and Mendel already described, it is evident that gliadin is representative of this group.

(3) "Incomplete" proteins: those which, as sole dietary protein, are incapable of supporting either growth or life. Zein clearly belongs to this class, as does also gelatin.

Any such grouping of the proteins, however, should be used with much discrimination, and with great care to insure an understanding of the quantitative aspects of the experimental data, if misconceptions are to be avoided. Edestin is a conspicuous example of a "complete" protein, having served as the sole protein food of a family of rats for three generations; but when the percentage of edestin in the food mixture was considerably reduced, results like those above described for gliadin were obtained—the diet did not support a normal rate of growth, but this could be secured by adding lysine to the food mixture. Similarly casein when fed in reduced proportion to the total food mixture did not support normal growth; but growth became normal when cystine was added (Fig. 18). Thus "complete" proteins may behave as "partially incomplete" when fed in reduced proportion. It is also to be remembered that varying rates of growth in different species (not to mention other differences) make inadmissible any broad generalizations as to the proportion in which any protein should be fed to species other than that with which its "completeness" or "incompleteness" has been demonstrated.

In 1916, Osborne and Mendel published quantitative measurements of the relative efficiency (for support of growth in young rats) of some of the "complete" proteins. The rate of gain obtained with 8 per cent of lactalbumin required 12 per cent of casein or 15 per cent of edestin; or, as they also state the results, "to produce the same gain in body weight, 50 per cent more casein than lactalbumin was required, and of edestin nearly 90 per cent more."

Lest we attribute undue weight to the differences between *individual* proteins, we should remember that practically all foods contain more than one kind of protein. Corn (maize), for example, in addition to the incomplete protein zein contains other proteins at least one of which yields all the nutritionally essential amino acids. Thus there is less danger of an incomplete assortment of amino acids in even a single food than in a single isolated protein. Nevertheless, the mixtures of proteins found in certain articles of food have higher nutritive efficiency than the natural mixtures in certain other foods because they contain the essential amino acids in proportions which approximate more closely the needs of the body. Thus, the various means of estimating relative values agree in indicating that proteins of animal origin are, as a class, superior in nutritive efficiency to those derived from plants. Of the animal proteins, those of whole milk and whole eggs share the first place. Next come the animal tissue proteins, among which those of liver and kidney probably have a higher value than those of muscle. Among the nutritionally important plant protein mixtures, those of the cereal grains, though inferior to most animal proteins, have nevertheless been found to possess a higher value than those of the legumes. But, though the natural protein mixture of milk is much more efficient than those of the grains, when grains and milk are fed together in favorable proportions, their proteins so supplement each other in furnishing the nutritionally essential amino acids that the combination may be practically as efficient as the milk proteins alone. This *supplementary relationship* between proteins is of great importance both nutritionally and economically, since it makes

possible the full utilization of the low-cost proteins of grains and other vegetable foods, provided only that they are fed in combination with sufficient amounts of those foods which reinforce their content of certain essential amino acids.

In the maintenance of full grown tissues, there need be no special anxiety regarding the adequacy of the amino-acid mixture yielded by the proteins of mixed diets such as are common in this country. But in cases in which new protein must be built up in the body, *e.g.*, growth, pregnancy and lactation, convalescence from a wasting disease, or feeding to build up a chronically undernourished person, the choice of proteins may become a matter of considerable importance. The proteins of milk and eggs are the ones best suited for conversion into body proteins. For this and other reasons it is highly desirable that milk or eggs or both be provided abundantly in the diet of growing children, of pregnant or nursing women, and of all people who require "building up."

A further discussion, which includes an analogy so widely quoted as to be rapidly becoming a classic, will be found on page 16 of Rose's *Feeding the Family*, 4th Edition (1940).

How Much Protein is Needed for Adult Maintenance?

Maintenance requirement is the amount required for nutritional equilibrium in the body.

Whether the body is in protein equilibrium or is gaining or losing protein, is ascertained by means of *nitrogen balance experiments*. These are experiments in which one determines, by means of chemical analyses of food and excreta, the amounts of nitrogen which enter and which leave the body, so that intake may be compared with output in a manner analogous to the balancing of a bookkeeping account.

We may say that the balance has been determined whenever the quantitative relation of intake and output has been ascertained. The body is said to be *in equilibrium* when intake and output are alike. The expression "in balance" is sometimes used synonymously, but is somewhat ambiguous because one has "determined the nitrogen balance" whenever

the intake and output have been ascertained and regardless of whether the data show equilibrium or not. Thus we meet the expression "plus balance" or "positive balance" when the data show that the body is gaining,—and "minus" or "negative" balance when the body is losing,—nitrogen or whatever other element may be under similar consideration (as phosphorus, calcium, and iron will be in subsequent chapters). The smallest intake which will support equilibrium, in a series of properly planned experiments, should indicate the body's requirement.

Using nitrogen as a practicable and sufficiently accurate measure of protein, each gram of nitrogen corresponds to approximately 6.25 grams of protein inasmuch as the mixed proteins of the body and of the food contain on the average 16 per cent of nitrogen. Nitrogen balance experiments, then, can be made to show the amount of protein which the food must furnish to maintain protein equilibrium in the healthy adult with (for our purpose) such a store of body protein as Americans and Europeans usually carry.

In 1920, one of us studied the available data which appeared to be applicable to the problem of the normal adult requirement. About one hundred such cases were found, and these gave a mean result of 0.634 gram of protein per kilogram of body weight per day with no significant difference per unit of body weight between the sexes (the means being 0.637 gram per kilogram for women and 0.633 gram per kilogram for men, wherein the apparent difference was less than its probable error).

Figured to the conventional basis of a body weight of 70 kilograms (154 pounds) this average finding was 44.4 grams of protein per man per day.

This has been somewhat generally used as an approximate measure of need or requirement in the sense explained above. As an estimate of *actual* need it is somewhat generous in that it contemplates the maintenance of a larger store of protein in the body than such careful students as Chittenden and Folin have deemed to be most desirable. The study of original

literature involved in collating the data averaged above left no doubt that in many if not most cases equilibrium could have been realized at lower levels of intake after the body had given up a relatively small fraction of the protein which it had been carrying; and no one can be sure whether and under what conditions the extra store of protein which most of us carry in our bodies is advantageous or not. Whether one believes in high-protein or low-protein diet is still somewhat a matter of temperament!

All of the generally accepted *dietary standards* for protein lean toward liberality as contrasted with actually demonstrated need.

A common custom has been to add fifty per cent to the above mentioned average of 44.4 grams thus arriving at a "standard" of 67 grams per 70 kilograms of body weight or, in round numbers, *one gram of food protein per day for each kilogram of body weight*. Or, with a shade more of liberality, 75 *grams for the average man of* 70 *kilos, and* 60 *grams for the average woman of* 56 *kilos* of body weight. This "75 gram standard" has recently received the endorsement of the Health Organization of the League of Nations.

Standards for Growth, Pregnancy, and Lactation, as Well as for Maintenance

The League of Nations "standard" of 75 grams protein for the man using about 3000 Calories, or 60 grams for the woman using about 2400 Calories, may also be stated as allowing one-tenth of the total calories in the form of protein.

This is a very rational recommendation as a guide in gauging family and population needs.

It had already been much used in the teaching of dietetics where the planning of a dietary often begins with the determination of the total food calories to be supplied, and then adds that "about 10 per cent" or "from 10 to 15 per cent" of the calories should be in the form of protein. The allowance of ten per cent is held to be ample by those who follow Chittenden in his advocacy of "physiological economy in nutri-

tion" or who particularly feel the need of economy as to cost, while an allowance of from ten to fifteen is sufficient to provide for those whose scientific judgments or whose temperaments lean toward a higher protein intake.

To set the protein standard as a given fraction of the total calories is also rational from the point of view that the relatively high food requirement of children applies about equally to their energy and their protein needs. And furthermore the reduction of total food calories in the dietaries of elderly people may well be paralleled by a proportionate decrease of protein.

In pregnancy and lactation the need for protein may perhaps be increased in somewhat greater ratio than the need for energy; and this is perhaps the strongest reason for sometimes setting the protein standard so high as to approximate the allowance of 15 per cent of total calories as protein.

Muscular work supported by an ample intake of food calories does not necessarily increase the amount of protein metabolized. In other words, the extra calories for the work could be supplied by increased carbohydrate (or carbohydrate and fat) without increase of protein; but usually it appears more practical and is found more acceptable to provide for the increased muscular activity by simply increasing the amount of the dietary of the accustomed kind.

Remembering, then, that it is not to be taken as implying that the need for protein varies with muscular activity, we may accept as a good guide for the planning or judgment of family dietaries or population food supply that we look first to the adequacy of the total food calories, and then to see that about ten or ten to fifteen per cent of the calories are in the form of protein.

To What Extent does Food Selection Influence the Nutritive Efficiency of the Protein Mixture which the Dietary Affords?

The problem of this chapter being how to meet the need for protein, its text may now be concluded with a brief

further consideration of the practical effect of differences in food selection.

As already mentioned, the natural mixtures of proteins which staple articles of food contain do not differ nearly so much in amino-acid make-up and resulting nutritive value as do the individual proteins when separated and examined as isolated substances. And a still further evening-up usually results from the presence of different natural foods in a dietary or community food supply.

These principles may be illustrated by the following facts regarding the proteins of wheat and of milk:

Osborne and Mendel, isolating from ordinary white flour its most abundant individual protein, gliadin, and feeding this alone, found it of relatively low nutritive efficiency,—"partially incomplete" in the sense explained above.

They also found, however, that other proteins in this same white flour made its protein mixture more efficient in nutrition than the gliadin alone.

Furthermore, they found that the protein mixture of whole wheat is of much higher nutritive value than that of white flour. They were able to make fairly satisfactory dietaries with whole wheat as the sole source of protein.

And finally, they and others found that the feeding of milk together with whole wheat gives a still higher nutritive efficiency or value to the protein mixture of the dietary. In the laboratory of the department of chemistry at Columbia, rat families are (February 1940) thriving in the forty-ninth generation on a dietary of five-sixths ground whole wheat and one-sixth dried whole milk with table salt and water. The proteins of this dietary constitute about 14 per cent of the dry food material and furnish approximately 14 per cent of its total calories.

So important are the supplementary relationships among proteins in ensuring good nutritive value of the protein mixture of any typical well-balanced dietary, that it does not seem essential here to enter into the discussion of the complicated attempts to set up methods for measuring and

expressing the more abstrusė socalled biological values, concerning the significance of which there is not yet a clear consensus of expert opinion.

More helpful and significant is the concept that dietaries or food supplies which are well-balanced with reference to their mineral contents and vitamin values carry very high scientific probability of being also well-balanced in the amino-acid mixtures, and in the nutritive efficiencies of the protein mixtures, which they contain.

EXERCISES

1. Feed parallel groups of young rats, starting at 3 to 4 weeks of age: (*a*) A mixture of 90 parts white flour, 9 parts butter, and 1 part table salt; (*b*) A mixture of 60 parts white flour, 30 parts milk powder, 9 parts butter, and 1 part of the same table salt. While the introduction of the milk will have enriched the diet in certain mineral elements and vitamins as well, the difference in growth during the first three or four weeks of this experiment may be attributed chiefly to the milk proteins.

(This experiment may then be continued to see what evidences of nutritional deficiency appear later and to interpret them in the light of subsequent chapters.)

2. Feed parallel groups of young rats, starting at 3 to 4 weeks of age: (*a*) Bread moistened with milk; (*b*) Bread of the same kind moistened with 5-per cent solution of milk sugar and spread with as much butter as corresponds to the milk used in (*a*). If the contrast here found differs from that found in the preceding Exercise, how do you explain the difference?

3. Plan experiments making use, if circumstances permit, of socalled "synthetic" diets (mixtures of artificially purified substances) between which the sole difference shall be: (1) an individual protein, *e.g.*, casein; (2) an individual amino acid, *e.g.*, lysine.

4. If facilities are available, carry out the experiments described in Exercises 1 and 2 and those planned in Exercise 3, continuing them as long as time permits, with daily feeding, watering, and casual inspection of the animals; and at least weekly weighings and careful physical examination.

In addition to the promptly-developing differences in growth, attributable to the protein (amino acid) factors discussed in the foregoing chapter, it is possible that a long-continued comparison

would develop other effects which, after your study of the chapters which follow, you might be able to attribute to some mineral or vitamin factor.

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Chapter VII

MINERAL ELEMENTS AND REGULATORY PROCESSES IN NUTRITION

The Mineral Elements

In preceding chapters we have discussed the composition and nutritive functions of foods principally in terms of the organic nutrients: carbohydrates, fats, and proteins. This has involved consideration of the elements carbon, hydrogen, oxygen, and nitrogen, which, as Table 5 shows, are the elements most prominent in the body's structure. In this chapter we shall be concerned with the twelve or more other chemical elements regularly found in the body which, although present there in much smaller quantities than the four elements just referred to, are nevertheless essential to its normal functioning.

These other elements are commonly designated as the *mineral elements* or the *inorganic foodstuffs*. But the use of such terms should not be understood to imply that these elements necessarily occur and function exclusively as inorganic or mineral compounds. For example, the most important compounds of sulfur in the food and in the body are the amino acids cystine and methionine which have already been considered as constituents of the proteins. Yet although sulfur thus enters and functions in the body almost entirely in organic combination it is, in the normal oxidation processes of the body, ultimately converted into the inorganic compound, sulfuric acid, and as such becomes an important factor in the mineral metabolism.

Which Mineral Elements are Essential?

It cannot be stated with certainty exactly how many of the mineral elements found in the body are indispensable to its normal structure or functioning; and how many are present merely through accidental introduction from the environment. *All eleven mineral elements* for which figures are given in Table 5 and also *cobalt* are now definitely regarded as essential, and the balance of contemporary judgment seems to favor the addition of *zinc* also to this list.

TABLE 5.—APPROXIMATE ELEMENTARY COMPOSITION OF THE BODY

ELEMENT	PERCENTAGE
Oxygen	65.
Carbon	18.
Hydrogen	10.
Nitrogen	3.
Calcium	2.[a]
Phosphorus	1.1[b]
Potassium	0.35
Sulfur	0.25
Chlorine	0.15
Sodium	0.15
Magnesium	0.05
Iron	0.004
Manganese	0.0003
Copper	0.00015
Iodine	0.00004
Cobalt	[c]
Zinc	[c]
Others of more doubtful status	

[a] Estimates vary widely.
[b] Percentage varies with that of calcium.
[c] Believed to be essential, but quantitative data are not yet at hand.

With regard to the question whether other elements are essential it seems clear that any diet which is adequate in the unquestioned essentials will almost certainly provide the traces at most that may be required of mineral elements whose importance is still unknown. And from this fact it follows that any element needed only in such small amounts that the need of it is still in doubt is very unlikely to be an actual limiting factor in nutrition, either in nature or in

civilized life; so that from the functional viewpoint of present-day science the elements to which we give attention in nutritional study for practical reasons are also undoubtedly the ones of really major scientific significance.

How do They Function?

The elements concerned in the mineral metabolism may exist in the body and take part in its functions in at least three kinds of ways:

(1) As constituents of the mineral matter of the bones and teeth, giving these structures their strength, rigidity, and relative permanence;

(2) As structural constituents of the soft tissues also, as illustrated by the fact that all the known tissue proteins contain sulfur, several of them as well as some other substances essential to cell structure contain phosphorus, and the outstandingly important hemoglobin of the red blood cells contains iron;

(3) As constituents of substances concerned in regulatory functions, as, for example, the salts held in solution in the body fluids and important in giving these their characteristic influence upon the functional capacities of muscle and nerve, their osmotic pressure, their solvent properties and consequent ability to transport the nutrients and their metabolites, and the property of supplying the material for the acidity or alkalinity of digestive juices while at the same time maintaining approximate neutrality in the blood and body tissues.

Varied as they are, these functions are interrelated at many points; and several of the socalled mineral elements take part in more than one of these three types of function.

Calcium and *phosphorus* function importantly in all three ways, and the preponderance of calcium phosphate in bone and tooth mineral makes them elements which the body needs in relatively large amounts. The next chapter will be devoted to them.

Iron, while occurring in much smaller amounts than

calcium and phosphorus, is nevertheless a real problem in nutrition, in the sense that if it is left to chance one does not always get enough, especially under our present-day conditions of living so largely upon artificially refined food. Inasmuch as the iron which enters into nutritional processes goes mainly to form hemoglobin, and *copper* has been found to play an essential rôle in the transformation of iron into hemoglobin, these two elements are discussed together in Chapter IX.

Iodine is an element which *in certain regions* is not sufficiently abundant to be safely left to chance, especially now that people commonly use such highly refined table salt. Here we meet a very special kind of nutritional problem, which seems best treated by itself in Chapter X.

Chlorine, in the form of its salts, the chlorides, plays a very important part in the maintenance of normal conditions in the body. That we do not (and need not) take account of chloride content in our ordinary judgments and studies of food values is due to our practice of adding so much sodium chloride (as common salt) to food in its preservation, in its preparation, and at the table.

The chlorides are among the most important of the body's *electrolytes*. These are substances which in water solution exist as electrically charged particles called *ions*. They function very significantly as regulators of body processes, both collectively, for example, in the control of the osmotic pressure of body fluids and hence of the passage of water into and out of the tissues, and *specifically*, as in their effect on the irritability of muscles and nerves, to be discussed below.

Sodium chloride, being by far the largest constituent of the mineral matter of the blood, assumes special significance in the regulation of water exchanges in the organism. And, as Cannon has emphasized repeatedly, these latter are more extensive and more important than may at first thought appear. He points out that "there are a number of circulations of the fluid out of the body and back again, without loss." Thus, for example, it is estimated that from a quart to

a quart and one-half of water daily "leaves the body" when it enters the mouth as saliva; another one or two quarts are passed out as gastric juice; and perhaps the same amount is contained in the bile and the secretions of the pancreas and the intestinal wall. This large volume of water enters the digestive processes; and practically all of it is reabsorbed through the intestinal wall where it performs the equally important function of carrying-in the digested foodstuffs. These and other instances of what Cannon calls "the conservative use of water in our bodies" involve essentially osmotic pressure relationships in which the concentration of sodium chloride plays an important part.

Under our ordinary conditions of everyday living the body is apt to receive and excrete several grams of sodium chloride per day, the amount varying with individual taste as to salting of food at the table and usually ranging considerably higher than is needed for maintenance of approximate equilibrium. In fasting, or on a salt-free diet, chloride output at first reflects to some extent the level of exchange of previous days, but rapidly falls to less than a gram per day. This fact, together with some reasons of a more medical kind, leads some physiologists and physicians to believe that a more moderate use of salt than the present-day liberal average may be better.

On the other hand, people engaged in occupations which induce profuse sweating may thereby excrete so much salt through the skin as to call (temporarily, at least) for an increased intake in food or drink.

Thus there are scientifically sound possibilities of occasions to safeguard the salt intake: sometimes against too much, and sometimes against too little. But most people at most times may eat their food "salted to taste" without anxiety in either direction; for the healthy body has power to adjust chloride output to chloride intake throughout a wide range (Fig. 19).

Potassium is especially prominent inside the cells of the blood and soft tissues, while sodium predominates in the

blood plasma and other inter-cellular fluids. And similarly (although their concentrations are much lower than those of sodium and potassium), magnesium is largely localized within the cells, while calcium is relatively more abundant in the fluids bathing the cells.

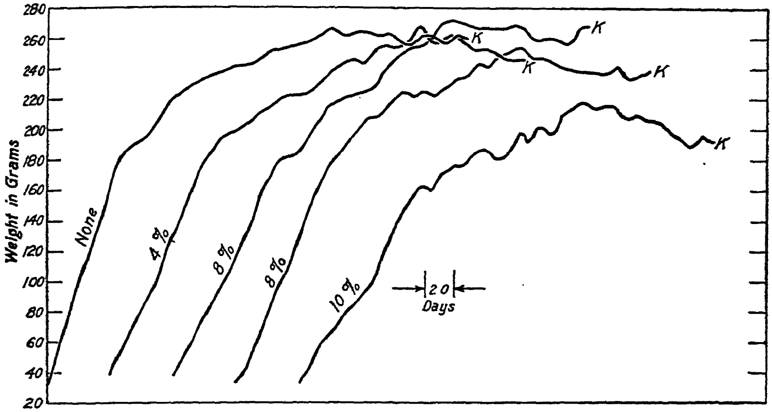

FIG. 19. Growth of male rats on a wheat-and-milk diet with different amounts of added table salt. Up to 4 per cent of salt in the dry food mixture (the curves for those receiving 1 and 2 per cent being here omitted to save space) there was no appreciable effect. At 8 per cent there are somewhat variable indications, and at 10 per cent a distinct indication of unfavorable effect.

However, the body fluids contain some of all four of these elements, and upon the balance between them depends largely the characteristic influence of these fluids upon the elasticity and irritability of muscle and nerve. The experiments of Howell, Loeb, and others on the heart afford a classic illustration of the individual and joint regulatory effects of various salts and their ions upon muscle tissue. It is well known that heart muscle may be kept beating normally for hours after removal from the body when supplied, under proper conditions, with an artificial circulation of blood or lymph or a water solution of blood ash. The sodium salts, being most abundant, take the chief part in the maintenance of normal osmotic pressure, which is one requisite for the continued life of the heart tissue. Aside from this property, sodium salts have a specific influence.

Contractility and irritability disappear if sodium salts are absent, but when present alone they produce relaxation of the muscle tissue. Calcium salts also, although occurring in blood in very much smaller quantity, are absolutely necessary to the normal action of the heart muscle; while, if present in concentrations above normal, they cause a condition of tonic contraction, or "calcium rigor"—in sharp contrast to the relaxation induced by sodium salts. Potassium salts, in the small quantities normally present, promote relaxation, through this effect tending to diminish the rate of heart beat; and in higher concentration cause a state of extreme relaxation known as "potassium inhibition."

Thus it is found that the alternate contractions and relaxations which constitute the normal beating of the heart depend upon a balance between calcium salts on the one hand and sodium and potassium salts on the other. Other active tissues of the body doubtless have analogous requirements as to inorganic salts.

In addition to the case just discussed, several other instances of socalled *ionic antagonism* might be cited. For example, *calcium* ion is in some measure antagonistic to *magnesium* ion. Thus, magnesium salts when administered in abnormally large quantities show a soporific and hypnotic action, which effect can be counteracted by the administration of calcium salts. Also the addition of magnesium to an otherwise well-balanced ration tends to cause a loss of calcium from the body. And, conversely, experimental magnesium deficiency results in an abnormal accumulation of calcium in the soft tissues.

Similarly, a high intake of *potassium* salts increases the excretion of *sodium* salts. Since most vegetable foods are relatively rich in potassium, Bunge suggested that this fact may afford an explanation of the craving for common salt which man shares with the herbivorous animals.

Various of the mineral elements have individual and specific functions in addition to their cooperative activities already indicated. For example, the presence of the calcium salts is

absolutely essential to the clotting of blood, while magnesium salts enhance the activity of the enzymes known as phosphatases and assist at certain stages in the metabolism of carbohydrates.

The prominence of calcium and phosphorus in bone has been mentioned. Small amounts of magnesium and sodium appear also to be constituents of the skeletal structures.

Manganese and *cobalt* are now generally accepted as nutritionally essential elements, but there is not yet a clear consensus of opinion as to what their normal functions are.

Sulfur (as already noted) enters the body almost entirely as a constituent of the organic matter of the food, yet it becomes an important factor in the mineral metabolism. The most important sulfur compounds of the food and of the body tissues are the sulfur-containing amino acids, cystine and methionine, of the proteins. The nutritional need for protein may, if one wishes, be discussed in terms of nitrogen requirement and of sulfur requirement; but in Chapter VI we considered it in terms of the need for different amino acids including those that contain sulfur, so that there here remains to be considered only the disposal of the end-products of the metabolism of cystine and methionine. Oxidation of these amino acids converts their sulfur into sulfuric acid which is eliminated chiefly as sulfate.

Thus what entered the body as a neutral element has become a strong "fixed acid" through the normal oxidation process of our metabolism. Even a moderate protein intake results in the formation of around two grams of sulfuric acid (sulfate ion) in the body every day. While the weight of carbonic acid simultaneously produced is many times greater, it leaves the body through the lungs without presenting the same sort of elimination problem as does the end product of the sulfur metabolism. This is discussed further under acid-base balance below.

Organic Acids

Except for the discussion of fatty acids in connection with fats and lipoids, the organic acids which occur in foods, and some of which also occur to an important extent in the

body, were only very briefly mentioned in Chapter II. It seems more advantageous to consider them at the present point because of their interrelations with the mineral metabolism, and particularly the part that some of them play in the phenomena of acid-base balance or the maintenance of the body's essential neutrality.

Perhaps we should first define the categories of acids with which the body has to deal from this point of view. Organic chemistry is, in the main, the same as the chemistry of carbon compounds; but we do not ordinarily consider carbonic acid as an organic acid. By *organic acid* (or organic acid radicle) we mean one which contains carbon and which can be burned. But of those which burn readily when heated in air, some do and some do not undergo ready and fairly complete oxidation in the body; and this distinction has an important bearing upon the problem of acid-base balance in foods and nutrition.

The present writers consider it an open question whether study of acid-base balance belongs strictly to the Essentials of Nutrition, or not. Those who do study it will do well to bear in mind four categories of acids: (1) organic acids readily oxidizable in the body; (2) organic acids not readily oxidizable in the body; (3) carbonic acid, "mineral" but "weak" and readily volatilized through the lungs; (4) fixed mineral acids, presenting a quite different elimination-problem from carbonic acid.

Before proceeding to the phenomena of acid-base balance, some of the organic acids deserve a few words on their own merits as nutrients.

Although the three major organic foodstuffs are practically neutral, certain foods as they are eaten are frankly acid, owing to the presence of substantial amounts of organic acids, such as citric, malic, lactic, and tartaric.

Of these, citric and malic acids are the most widely distributed, one or both of them occurring in appreciable concentration in practically all vegetables, and still more

abundantly in fruits. From Table 28, in Appendix D, which gives approximate amounts of these acids found by Hartmann and Hillig in certain fruits, it can be seen that malic acid is the chief acid in apples, cherries, peaches, plums and quinces; while citric acid predominates in currants, grapefruit, lemons, loganberries, oranges, pears, pineapples, raspberries, strawberries, and tomatoes. Milk also contains citric acid to the extent of about 1.5 grams per liter.

The body seems able to burn as fuel practically all of the citric acid any diet is likely to contain, forming carbon dioxide and water to be disposed of along with the same products from the metabolism of other organic foodstuffs. Less is known of the fate of malic acid in the human body; but since cats, rabbits, and dogs burn it fairly readily, it is presumed that man also has this ability.

So far as is known, tartaric acid occurs abundantly only in grapes. When these are eaten, the tartrates which they contain appear to be largely broken down by the bacteria in the digestive tract. It is said that only a small fraction, if any, of the tartaric acid is absorbed from the intestines; and that the body tissues have almost no ability to destroy the tartrate which does reach them. Whether, and to what extent, the eating of grapes presents the body with a problem of acid disposal will thus depend upon the degree to which the tartrate radicles are absorbed; and this apparently differs largely among individuals.

Lactic acid is prominent in buttermilk and in sauerkraut and certain other fermented foods.

Acetic acid is found in vinegar, and in pickles and other foods prepared with it.

A substance known as quinic acid is present (along with other organic acids) in plums, prunes, and cranberries. The body cannot carry the breakdown of this substance completely to carbon dioxide and water, but another organic acid, hippuric acid, is the end-product.

Acid-Base Balance in the Body

The normal condition of the blood, and, so far as we know, of the tissues generally, is very nearly neutral. Neither a distinctly acid nor a strongly alkaline condition of the blood, or of the system generally, is compatible with health or even with life. The maintenance of this condition of approximate neutrality is what one usually has in mind when one speaks of the problem or the phenomena of acid-base balance in the body.

Acidosis is a technical term in medicine, now used in a very special and restricted sense. It designates that condition in which the oxidation of fatty acids in the body, instead of proceeding completely to carbon dioxide and water, halts at an intermediate stage with the formation of acetone, aceto-acetic acid, and beta-hydroxybutyric acid as end-products. Any discussion of this highly special problem of acidosis belongs to medicine and not to the normal nutritional problem or phenomenon of acid-base balance.

Acid-base balance in normal nutrition has to do with the disposal of the acid-forming and base-forming elements in such manner as to maintain a general condition of approximate neutrality within the body. The more precise definition, the limits of variation, and an explanation of the "chemical mechanism" by which the nearly constant condition of approximate neutrality is maintained, are necessarily somewhat technical and involve a more chemical approach than that of the present text.

Carbohydrates and fats when normally oxidized in the body yield carbon dioxide which is eliminated through the lungs by a physico-chemical process of marvelous efficiency and great theoretical interest to the chemistry of general physiology; but which from the viewpoint of our present study may be said to be so nearly automatic as not to constitute a responsibility of nutrition in the ordinary sense.

Proteins of course yield carbon dioxide too; but the more distinctive end-products of their metabolism are the nitrogen compounds, from all the amino acids, and the sulfuric acid (sulfate ions) from those which contain sulfur. It is the formation of a considerable amount of such a strong, fixed (non-volatile), acid as sulfuric, from the previously neutral sulfur of food protein, which makes some students of nutrition (including some, but probably not most, physicians) feel that there is an acid-base problem which lies within the distinctly nutritional responsibility of food selection.

In this sense, it is a problem involving both the proteins and the salts or ash constituents of the food.

Some of the proteins contain phosphorus and thus yield phosphoric, as well as sulfuric, acid in metabolism; while many foods contain significant amounts of other organic compounds of phosphorus and also of phosphoric acid radicles (phosphate ions) in the form of mineral or inorganic salts.

Chlorine completes the list of the three *fixed-acid forming* elements which enter in significant amounts into the problem; but here the acid radicle is entirely pre-formed in the food as it enters the body.

To balance the (fixed-) "acid-forming" elements (sulfur, phosphorus, and chlorine) the food furnishes significant (though quite variable) amounts of four "base-forming" elements: sodium, potassium, calcium, and magnesium. Also we find that a variable proportion of the nitrogen from protein metabolism leaves the body as ammonium salts of fixed acids (often called "ammonia"), indicating that a part of the "waste" nitrogen from protein metabolism may on occasion help out the base-forming elements in the maintenance of body neutrality. Most of the nitrogen, however, is excreted as the essentially neutral substance, urea.

In normal nutrition the "problem" of acid-base balance is chiefly that of elimination of surplus fixed acid, especially that formed from the oxidation of the sulfur of the food protein. This surplus fixed acid is taken care of chiefly in two ways: (1) by elimination of nitrogen as ammonium salt as just explained; and (2) by the secretion of a more acid urine, which usually means a larger proportion of *acid* phosphate in the urine. In case the surplus of fixed acid is small or transient, a shifting of the proportions of between mono- (primary) and di- (secondary) phosphate may suffice; but beyond this, the increased excretion of primary phosphate may involve increased excretion of total phosphate necessarily carrying with it some fixed base and thus tending to deplete the body's *alkaline reserve.*

As a precaution against such depletion, it is sometimes thought worth while to balance the foods in which (fixed) acid-forming elements predominate ("acid-forming foods") by including in the diet corresponding proportions of "base-forming" or "basic" foods (foods "on the alkaline side") which contain more than enough of fixed base-forming elements to neutralize the fixed acid formed by the metabolism of these foods.

Meats and fish, eggs, and grain products are acid-forming foods

in the sense here explained. Their acid-forming character can not be adequately demonstrated by burning in air and testing the ash, because the surplus sulfuric acid is driven off by such heating in air.

Table 6 shows the relative acid-forming properties of some such foods per 100 grams and per 100 Calories.

TABLE 6.—A FEW OF THE FOODS IN WHICH ACID-FORMING ELEMENTS PREDOMINATE

FOOD (Edible Portion)	APPROXIMATE POTENTIAL ACIDITY (cc. Normal Acid)	
	Per 100 Grams	*Per 100 Calories*
Beef, clear lean	12	10
round steak	11	7
Eggs	11	7
Oysters	15	30
Oatmeal	12	3
Rice	9	2
Wheat, entire	12	3
Wheat flour	9	2
White bread, made with water	6	2

Table salt and all foods which are practically without protein or natural ash constituents may be regarded as neutral in metabolism.

Base-forming elements predominate slightly in milk and to a more pronounced degree in most fruits and vegetables, of which some typical illustrations are given in Table 7. Foods such as the citrus fruits are *acid as eaten but base-forming or "on the alkaline side" in metabolism* because their organic acid radicles (whether present as free acid or as acid salt) are largely or completely burned in the normal oxidation processes of the body.

At present it should be frankly recognized that there are differences of opinion as to the significance of the acid-base balance of foods among those who are such able and thoughtful students of the subject as to entitle their views to respect. Some hold the regulatory "mechanism" of the normal body to be so efficient that the balance of acid-forming and base-forming elements in the food is of no consequence to nutrition and health. Others, agreeing that the blood maintains its neutrality with great efficiency, still think that the body is better off when it is not forced to excrete a markedly acid urine. We may doubtless accept the evidence of experience that many people have been benefited by

TABLE 7.—A FEW OF THE FOODS IN WHICH BASE-FORMING ELEMENTS PREDOMINATE

FOOD (Edible Portion)	APPROXIMATE POTENTIAL RESERVE ALKALINITY (cc. Normal Alkali)	
	Per 100 Grams	*Per 100 Calories*
Apple	3	6
Banana	8	8
Cantaloupe	7	18
Carrot	14	30
Orange (or juice)	5	10
Pear	4	5
Potato	9	10
Tomato (or juice)	5	24
Watermelon	4	12

giving a higher place to fruits and succulent vegetables in their daily dietaries; but how the credit for the benefit is to be distributed between base-forming elements and vitamins is as yet an open question. In our opinion more of the newest knowledge of nutrition is needed before anyone can confidently attempt a conclusive weighing of the evidence.

EXERCISES

1. Put about 10 grams of grapefruit juice in a platinum or silica dish. Show that the juice is acid. Evaporate it to dryness and burn it to ash. Show that the ash is alkaline.

2. Explain why the typical "acid-forming" foods do *not* yield a correspondingly acid ash when burned in the air. What acid, produced in significant amounts in metabolism, is a "fixed acid" in the body, but is volatilized when heated in an open dish?

3. With the facilities available to you, can you show that the urine is rendered less acid by eating oranges or grapefruit, more acid by eating lean meat or eggs?

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Chapter VIII

PHOSPHORUS AND CALCIUM

Occurrence and Functions of Phosphorus

Phosphorus occurs in the body as a constituent of many of its materials, and functions in many nutritional processes. A glance at its occurrence in nature is of interest as introducing us to "the phosphorus problem" of nutrition and of food supply.

The late Dr. F. W. Clarke, long the chief chemist of the United States Geological Survey, estimated that phosphorus constitutes 0.11 per cent of the crust of the earth; but it is rather unevenly distributed, and largely locked up in the form of phosphate rocks some of which are very resistant to weathering and so yield their phosphates but slowly to the soil. Hence phosphorus is one of the elements in which soils are most often poor, relative to the needs of the plants which grow upon them. For about a hundred years the attitude of science has been that the phosphate fertilization of the soil may be expected to result in larger crops, rather than crops containing significantly higher percentages of phosphorus.

Within the past thirty years, however, it has been found, first in South Africa and thereafter in several other parts of the world, that phosphorus-poor soils may produce phosphorus-poor forage with resulting tendency to shortage of phosphorus in the nutrition of cattle obliged to subsist on such pastures.

The general tendency in plants is toward a relative concentration of calcium in the leaves and of phosphorus in

the seeds. Hence pasture-plants become poorer in phosphorus in the late summer and autumn when the seeds have fallen to the ground. And in general, there is relatively more danger of shortage of phosphorus in the leaf diet of grazing cattle; and of calcium deficiency in the dietaries of people who eat relatively little of leaf foods and relatively large amounts of seeds and their milling- and bakery-products. However, it would not be scientifically justifiable to ignore the phosphorus problem of human nutrition. (At the "rickets age" phosphorus may be the limiting factor in the body's development.)

Phosphorus is an essential constituent of every known tissue and cell in the body. Although probably nearly 90 per cent of the total phosphorus of the adult body is in the skeletal system, yet the amount and the wide distribution of the phosphorus compounds of the soft tissues including the body fluids, give them a position in the active metabolism of the body fairly analogous to that of the proteins, although the total amounts involved are not so large.

Amount of Phosphorus Required

With phosphorus functioning in so many ways in the body, considerable interest attaches to the question of the amount which the body must receive daily from the food in order to meet the needs of replacement of the phosphorus spent in connection with these functions.

From the data of about one hundred studies, each of some days' duration, in which the quantitative balance of intake and output of phosphorus was determined in a manner analogous to the nitrogen-balance experiments described in Chapter VI, an average of 0.88 gram of phosphorus per man per day was found to be required for the maintenance of healthy adults in nutritional equilibrium. For much the same reasons as with protein, it is customary to add fifty per cent when setting a "dietary standard."

Amount of Calcium Required

In the manner just described for phosphorus, and again in about one hundred experiments each of some days' duration, the calcium requirement of adult maintenance appeared to average 0.45 gram per day; while other experiments and a different method of interpretation have given an average of 0.55 gram.* Thus the minimum amount on which approximate equilibrium can be maintained in adults may be regarded as fairly definitely established at about 0.5 gram of calcium per day. This, however, is a "rock-bottom" base figure to which an allowance of 50 per cent or more should be added if one desires a "standard" for dietary practice or for interpreting the adequacy of a food supply. The outstanding facts to be considered in this connection are three: (1) On account of individual differences and the frequency of digestive conditions which diminish the efficiency of the utilization of calcium, the percentage margin needed for insurance of adequacy is probably larger with calcium than with protein and phosphorus. (2) In the development of bones and teeth, as also in pregnancy and lactation, the need for calcium is markedly accentuated. (3) It is now well established by very comprehensive laboratory investigations continuing throughout entire life-times and successive generations of experimental animals, that increasing liberality of intake of calcium continues to give increasingly beneficial results up to much higher levels than previously supposed.

What is the Extent of the Margin of Optimal Over Adequate Intake, and What Difference Does It Make?

Leitch**, whose interpretation favored 0.55 gram rather than 0.45 gram as the minimum for maintenance of adult equilibrium, also held that an intake close to 0.55 gram per adult per day cannot be depended upon to support for long a

*Apparently, the earlier and later experiments agree very closely in their actual average *data;* and the fact that the later average is higher is chiefly due to a different method of *interpreting* the experiments.

***Nutrition Abstracts and Reviews*, 1937, 6, 553–578; 1938, 8, 1–2.

fully normal condition of health; that for permanent health, even if there is no demand beyond that of mere maintenance, a materially higher intake should be provided. We believe that this view is supported by a good deal of (somewhat fragmentary) evidence directly from human experiences of different kinds. Certainly it is very clearly borne out by well-controlled experimental evidence of extensive and intensive research with laboratory animals, of the species chosen because of the close resemblance of its nutritional processes to ours in this as well as in most other respects.

Using rats as experimental animals, the nutrition laboratory of the Columbia University department of chemistry studied the effects of different quantitative proportions of wheat and milk in dietaries which, for the sake of certainty of interpretation, were simplified to consist of these two foods with table salt and distilled water. It was found that five-sixths ground whole wheat with one-sixth dried whole milk (Diet A) made an *adequate* food supply, but that a mixture of two-thirds ground wheat and one-third dried milk (Diet B) was *better*. Compared with those on Diet A, the animals on Diet B showed more rapid and efficient growth and development (corresponding to the freshmen entering college taller yet younger), higher adult vitality, and a longer prime of life. While popular attention was attracted by the fact that the adult life expectation or "life cycle" was extended by about ten per cent, it is chiefly worthy of emphasis here that undoubtedly the "health as a positive quality of life" was higher at every age.

In terms of the set-up of the original experiment, the variable factor in the dietary was the quantitative relation of its two major ingredients: wheat, taken as typical of foods furnishing energy at low cost; and milk, as representative of the "protective" foods needed to "balance" the dietary. Then the investigation was extended into the study of the individual chemical factors involved.

Increase of the proportion of milk had enriched the dietary by about 60 to 90 per cent in each of the three factors cal-

cium, vitamin A, and riboflavin (which we formerly called vitamin G, or part of the vitamin B_2 complex); and also involved a minor increase of the protein value. Each of these factors has since been studied separately. The experiments with different levels of calcium intake are of interest at this point.

It has been found in these recent experiments that differences of calcium intake (of the calcium content or "calcium level" of the dietary or food supply) *both above and below* the "just fully adequate" level, such differences as are known to be of frequent occurrence in human experience, have a larger and more far-reaching significance for nutritional well-being and health than hitherto supposed.

Low-calcium dietaries fairly good in other respects may support growth and apparently normal health to an extent which by previous standards would have indicated adequacy, but in the course of a life time or of two generations a heavy penalty may be paid for subsistence on such a low calcium level. Doubtless such penalties have been and are being paid by many people and attributed to other causes (or to bad luck in one's constitution) in complete ignorance of the fact that the ultimate cause has been the paucity of calcium in the family food supply for perhaps more than one generation. In families of experimental animals studied by Campbell, Bessey, and Sherman, a calcium intake of about 0.1 per cent of the dry food, or about 0.02 gram per 100 Calories, sufficed for good growth and an appearance of good health in the first generation but not in the second. The second generation animals were only slightly undersized but their percentages of body calcium were distinctly subnormal, they were unable to launch a third generation, and they showed signs of senility unduly early.

The calcium content of the above-mentioned Diet A (Diet 16 of the original laboratory records at Columbia University and some of the more technical papers therefrom) was 0.19 to 0.20 per cent of the dry food mixture, which appeared to be about the minimal level fully adequate for

permanently normal nutrition, generation after generation, and was therefore adopted as the base-line for the planning, experimentation, and interpretation in the investigation of the effects of higher levels of intake, *i.e.*, of dietaries or food supplies of higher calcium content. When we speak of higher levels in terms of their quantitative relation to the "minimal-adequate level," this latter means something of the order of 0.16 to 0.20 per cent calcium in a dry food. Greater precision is not sought at this point for two reasons: (1) Too great pretentions of precision might be misleading when we are using one species as experimental subject in studying the nutritional problems of another; and (2) we find it sufficiently ambitious for the present to attempt a general grasp and sense of proportion as to the extent of the margin between the merely adequate and the optimal calcium intake, and of the difference which the more liberal intake makes in nutritional well-being, buoyancy of health, and resulting efficiency or quality of life, both in youth and in maturity.

When, without other change, the above-mentioned Diet A was increased in calcium content to 0.35 per cent (about twice the minimal adequate level) there resulted better growth, earlier maturity, higher adult vitality, a longer "period of the prime" between the attainment of maturity and the onset of senility, and an increase in the average length of adult life or "life expectation of the adult." (Sherman and Campbell, 1935.)

In the experiments just mentioned the increased length of life was clearly significant with the males but much less with the females, which however had invested their increased allowance of dietary calcium in the bearing and suckling of an increased number of young. When, in a subsequent series of experiments, the calcium content of the diet was raised to a still more liberal level, the females were enabled *both* to bear and rear more young *and* to enjoy higher health and longer life.

Establishment of the fact that in the case of calcium there is a much wider zone than had hitherto been suspected

between a minimal-adequate and a truly optimal level of intake (or, differently expressed, a much larger fi potential improvement of the already normal) accentuated interest and significance to the problems of the influence of nutrition upon the chemical composition and internal environment of the normal body.

Analyses of large numbers of the offspring of parallel families of laboratory animals (rats) on diets containing on the one hand a little over the minimal-adequate calcium content and on the other hand from three to four times as much have shown that this liberal increase over a level of intake already adequate for normal health and development results in a higher percentage of calcium in the body at a given age or size. The difference becomes measurable very early in life, is greatest during the period of most rapid growth, and is still significantly measurable in the adult. All the evidence indicates that this more rapid calcification of the skeletal system is advantageous to the nutritional well-being and positive health both at the time and throughout the subsequent life of the individual whose development has been thus expedited by a liberal calcium content in the family food supply.

As previously noted, 99 per cent or more of the calcium retained by the body takes the form of the relatively resistant bone and tooth minerals of the skeletal system. The question therefore arises whether an increased amount of such sparingly soluble calcium salt in the body's hard structures will significantly influence the concentration of calcium in the soft tissues and body fluids. Here it is of great interest that different investigators, using different species, have consistently found that increased retention or storage of calcium in the body involves increased development of the bone *trabeculae*. These are delicate crystals of calcium salts which grow from the inner surfaces of the ends of the bones, forming, when abundant, a mesh-work of material in the bone cavities, especially near their ends. As the walls of the bones are at their ends so porous and vascular as to consti-

tute an important part of the path of the circulating blood, the nutritionally-induced differences of trabecular development, as illustrated in Fig. 20, result in large differences in the surface area of calcium-containing material with which the blood comes in contact in the course of its circulation. Thus the larger the store of body calcium and the development of the bone trabeculae the more steadily is the *full* normal concentration of calcium in the blood, lymph, and soft tissues maintained. This is probably of great importance (though perhaps not yet fully appreciated) because so many vicissitudes in our life processes result in small losses of calcium which temporarily lower the concentration of calcium in the blood, the full maintenance or quick restoration of which plays so essential a part in the body's self-regulatory processes. Hence even though the body's calcium reserve is laid up in a form of such slight solubility yet the more abundant the reserve the greater the calcium-saturating surface with which the circulating blood has contact and the quicker the restoration of a normal blood calcium level whenever this has been depleted in any way. Moreover, as we are only now beginning to appreciate, a normal range of blood calcium concentration which looks narrow enough from the viewpoint of current accuracy of analytical determination may still be wider than the zone of strictly *optimal* concentration. For instance, it may be said that the normal serum calcium concentration is 0.009 to 0.0115 per cent, and that the analytical determinations now current are hardly precise enough to justify attempting a more refined estimate; yet it may at the same time be true that the individual having such rich development of bone trabeculae as to ensure an almost constant maintenance of something

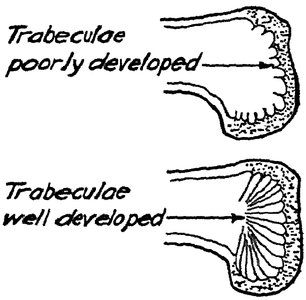

FIG. 20. Diagrammatic representation of the bone trabeculae as affected by the calcium content of the food.

near the maximum of these values may have an advantage over the individual whose blood calcium even though within the normal range is more often in the lower levels of this zone. Thus differences in a body's reserves of even such an insoluble asset as the calcium in the bones may very really and significantly influence the internal environment in the sense of the quantitative chemistry of the fluids and soft tissues of the body which directly and immediately environ its life processes.

Calcium and Phosphorus in Growth and Development

Flexibility of the body at birth is an obviously advantageous property and is well fixed in our species as well as in several others. But flexible bones must mean skeletal structures in a less calcified condition than in the normal adult. Thus we are all born calcium-poor; and normal growth and development call for a marked increase not only in the amount but also in the percentage of calcium in the body. The same is true, in less degree, of phosphorus.

The quantitative relations have been determined most fully and accurately in the case of the rat, where representative individuals of different ages can be taken in large numbers from well controlled colonies, and the entire body subjected to chemical analysis. Here it was found that the growth and development of the body to normal adult status involved a 75-fold increase of body weight over that at birth; an increase of 150-fold in the amount of phosphorus, and of 340-fold in the amount of calcium, which was contained in the body at birth.

The quantitative relationships are less extreme in the case of the human being which is born with something like one-twentieth of its adult weight and with bones correspondingly more calcified than those of the new-born rat.

The stage of skeletal development which the rat shows at birth is that of before-birth in a normal baby, and the new-born baby's skeleton is perhaps comparable in its stage of development to that of a rat about two weeks old. Still,

the normal development of the baby involves not only a great deal of growth, but also and at the same time a great deal of hardening, of its bones.

Thus during growth and bodily development there is a relatively much accentuated need for calcium as compared with the needs for tissue building materials of other kinds.

The inevitable fact of being born calcium-poor is to be regarded as advantageous to the event of birth itself, but as a nutritional handicap thereafter. To enable the growing body to overcome this handicap without undue delay, to build a good skeletal framework and a sound set of teeth notwithstanding the fact that it started life under the handicap of a low calcium content, requires a food supply richer in calcium than many people find easy to realize.

Thus there is a very real "calcium problem" in human nutrition; and not only in infancy but throughout the period of rapid growth and development. Todd and his associates in their anatomical studies found a large proportion of skeletons subnormally calcified; Jeans and Stearns find that children differ markedly in the efficiency with which they utilize food calcium; and Leitch, holding with Todd and with Jeans that the optimally developed skeleton is considerably more highly calcified than has hitherto been realized, estimates that standards for calcium intakes and retentions should be higher than in the past.

Even among investigators who have given special attention to the calcium retentions of growing children, there are still differences of interpretation. One regards the finding of a relatively high retention as evidence of good practice in feeding; another, as evidence that calcification had previously been abnormally retarded. We have endeavored to exclude cases of the latter kind from the averages which appear on the last line of Table 8; but some critics may still regard these estimates as representing a higher level of retention than can be sustained throughout the first nine years of life.

We therefore propose as a "standard" which we believe

TABLE 8.—DIFFERENT ESTIMATES OF NORMAL RETENTION OF CALCIUM DURING GROWTH AND DEVELOPMENT OF THE HUMAN BODY: RETENTIONS IN MILLIGRAMS PER DAY

AGE:	1ST YEAR	2ND YEAR	3RD YEAR	4TH YEAR	5–9 YEARS	10–15 YEARS	16–22 YEARS
Shohl's average "from the literature" (adapted)...........................	163	110	90	68	136	190	65
Macy's average (adapted) probably mainly of more recent data..................	189	276	276	180	220	260	32
An average of recent data compiled by the present writers.......................	220	235	286	246	238	192	?

to be thoroughly practicable: One gram of calcium per day in the food of children of all ages; with the expectation that 20 per cent of this intake or 0.2 g. per day will be retained, and that this rate of retention will continue until the developing body has attained to the same *percentage* of calcium which it will subsequently maintain.

This would mean the retention, during the early years, of 73 grams of calcium per year. Allowing for 20 grams of calcium in the body at birth, and for average growth in body weight, this would result in the body containing about 1.95 per cent of calcium at the age of 4; and a little over 2 per cent at the age of 9 years. Whether the body thus early equipped with a good framework will thereafter continue to increase its percentage of calcium is still an open question. In any event, the evidence obtained from laboratory animals favors the continuance of the dietary standard of 1 gram of calcium per day for all ages.

As mentioned above, relatively more calcification occurs before birth in the child than in the rat. What the rat mother does in supplying her offspring is done predominantly during the suckling period, whereas the human offspring makes heavy demands upon its mother for calcium not only in lactation but in the latter part of pregnancy also. The calcium requirement of embryonic development must obviously be met through the mother, and is a matter of concern to her as well as to the baby. Recent estimates have tended to increase the allowance for calcium requirements during pregnancy; and also during lactation so long as the baby is getting most of its nourishment by breast-feeding. Obviously then, the calcium requirement of the baby for the growth and development which it makes before its birth is a fairly large "fixed charge" collected through the mother and at the cost of her body unless it is amply supplied by her food; while the baby's requirement after its birth is met through the mother to the extent that she nurses it, and for the rest from its other food.

The Problem of Dietary Standards for Phosphorus and Calcium

Rose's *Laboratory Handbook for Dietetics*, 1937 Edition, suggests that *of phosphorus* an adult man should receive 1.32 grams per day, while a child should have not less than 1 gram per day; and *of calcium* for an adult 0.68, and during growth, or pregnancy, or lactation, at least 1.0 gram per day.

In 1938 the League of Nations Health Organization proposed an allowance of 1.5 grams of calcium per day during pregnancy and lactation, with a scale of allowances for other adults and for children of different ages which bring the population allowance to 0.9-1.0 gram per capita.

In the food-supply calculations of the U. S. Department of Agriculture, Stiebeling uses*:—

Calcium allowance: Men, 20 years and over, 0.68; women, 20 years and over, 0.88; children under 20 years, 1.00 gram per day.

Phosphorus allowance: Adults, 20 years and over, 1.32; boys, 13-19 years, 1.32; boys 9-12, girls 11-19 years, 1.20; boys 4-8, girls 4-10 years, 1.00; children under 4 years, 1.00 gram per day.

It is to be kept carefully in mind that the use of the word "standards" in this connection is a case of over-expression; we use it here only because of its currency. These so-called standards are in practice usually either (1) guides for use in planning dietaries, or (2) conventional means of putting records of food consumption or food supply upon a comparable basis. The word standards suggests a finality which is not true to present knowledge, and an inflexibility which would be of doubtful scientific value in any case.

As guides the so-called dietary standards aim at a level of intake enough above the "rock-bottom" average of minimal need to cover the individual variations and the

*Stiebeling, H. K., and E. F. Phipard: U. S. Dept. Agriculture, Circular No. 507, page 50.

day-to-day fluctuations of efficiency in utilization which are apt to be met among normal people.

The general plan of allowing a margin of about 50 per cent seems in the present state of knowledge as well suited to phosphorus as to protein; and this indicates an allowance of about one gram of phosphorus per day for children, 1.32* for adult maintenance, and 1.65** during pregnancy and lactation.

Attempts to assign corresponding allowances or standards for calcium meet, at present, two major difficulties. The estimates of normal calcium retention in childhood, and of calcium content of the human body at a given age, still differ widely; and the fact that the margin between adequate and optimal intake is exceptionally large in the case of calcium is too newly established to have yet been fully assimilated into the concept of the "standard." There are also rather wide community differences in the age distribution of the population and the average duration of breast-feeding. And until all families are educated both to a knowledge of nutrition and an appreciation of its importance, we cannot expect elaborate sets of standards for different ages and conditions to become fully effective. It is perhaps equally probable that progress will be made *chiefly* by a gradual shift of the food habits of the people as a whole in the directions which the newer knowledge of nutrition shows to be better on the whole and in the long run. It is now definitely established that one of the directions for improvement of nutritional well-being and resultant higher health is an increase of calcium intake. As a convenient round figure guide, we commend the suggestion that calcium intakes as calculated from food supply or food consumption data be considered in relation to *a standard of* 1.0 *gram per capita per day*.

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*Fifty per cent above adult maintenance (0.88 × 1.5) equals 1.32.

**One-fourth more than the "standard" of 1.32 equals 1.65.

Selection of Foods to Provide Calcium and Phosphorus

The calcium and phosphorus of the food have come, of course, ultimately from the soil (and the "ground waters" contained in it). Of late, there has been a tendency in some quarters to emphasize, perhaps unduly, the effect of soil and fertilizer upon the percentages of mineral elements in the resulting crops. Some striking assertions on this point are as yet accompanied by no quantitative data. At the Rhode Island Agricultural Experiment Station, however, a comprehensive quantitative study has been made of the influence of soil and fertilizer upon the phosphorus content of turnips. Quantitative determinations of phosphorus were made in 137 similarly prepared samples representing turnips grown upon a wide variety of soils, in some cases without fertilization and in other cases with fertilizers differing greatly in kind and amount. It would seem that this investigation should have revealed about the extreme variability which differences in soils and their fertilization can induce; yet the coefficient of variation (C. V.)* of the 137 cases was only 35, or only about twice as great, even under these extreme conditions, as that of the data of the carefully controlled experiments upon which is based our knowledge of the body's phosphorus requirement, the latter showing a C. V. of 17.

Thus even under highly extraordinary variations of soil and fertilization the phosphorus content (according to the best available evidence) shows only moderate variability, when all the data are taken into consideration as should be done in any scientific discussion of variations. It would be true, but also it would give an exaggerated impression and therefore would not be a scientifically sound way of reporting or discussing the findings, to say that the phosphorus contents of these turnips varied from 0.11 to 0.72 per cent or "by 550 per cent" of the minimum. For while this is a true statement so far as it goes, it relates only to the *two least representative cases* in a series of 137. All the other 135 findings

*This and some other simple statistical terms are explained in Appendix E.

are nearer to each other than the two which constitute the minimum and the maximum. The most generally accepted and serviceable way of giving a scientifically sound statement of variation is in terms of the statistical coefficient of variation (or coefficient of variability, C. V.).

Of the other edible roots,—beets, carrots, parsnips, radishes, and sweetpotatoes,—of which we have from 9 to 32 records each of calcium and phosphorus determinations, the coefficients of variation range from 12 to 54, the calcium content appearing on the whole slightly more variable than the phosphorus content. Both the calcium and the phosphorus contents of such *edible roots* are usually between 0.03 and 0.05 per cent.

The starchy potato tuber contains a similar amount of phosphorus but distinctly less calcium.

In general, the *bulbs, stems*, and *twigs* are similar in calcium and phosphorus content to the roots, while *leaves* are richer in calcium, and *flowers* and *seeds* are richer in phosphorus. Analyses of the edible twigs, the flowerbuds, and the leaves of the same samples of broccoli resulted as shown in Table 9.

Table 9 shows the calcium and phosphorus contents of typical foods of both animal and vegetable origin. Data for calcium, phosphorus, and iron, and for some of the vitamin values, of about 200 other foods may be found in Table 27, Appendix C.

Green leaves, as of the loose-leaf varieties of cabbage and lettuce, contain much more calcium than the relatively colorless inner leaves of the headed varieties, though the phosphorus contents are about the same. Spinach and other leaf foods of "the goosefoot family" (Chenopodiaceae, including beet greens, chard, and spinach) have been found to contain relatively large amounts of oxalic acid which interferes with the utilization of calcium. The Compositae (including dandelion, endive, escarole, and lettuce) and the Cruciferae (including broccoli, cabbage, kale, turnip greens, and watercress) contain only insignificant amounts of oxalic acid and are correspondingly better sources of calcium.

TABLE 9.—CALCIUM AND PHOSPHORUS CONTENTS OF TYPICAL FOODS

FOOD	CALCIUM	PHOSPHORUS
	percentage	*percentage*
Foods of Animal Origin		
Bacon, average......	0.006	0.108
Beef, lean muscle....	0.013	0.204
Eggs...............	0.063	0.224
Milk...............	0.118	0.093
Cheese, Cheddar type	0.930	0.701
cottage......	0.082	0.263
Grain Products		
Oatmeal............	0.065	0.387
Wheat, entire.........	0.053	0.374
White flour...........	0.015	0.101
White bread..........	0.05[a]	0.10[b]
Fruits and Vegetables		
Apples...............	0.007	0.012
Broccoli, flowerbud...	0.089	0.111
leaves.......	0.318	0.067
twigs........	0.073	0.038
Oranges..............	0.024	0.018
Potatoes.............	0.013	0.053

[a]The calcium content of bread varies from about 0.02 to about 0.08 per cent according to the amounts of milk solids and "yeast food" used.

[b]Phosphorus also varies with ingredients used in breadmaking, but not so much as does the calcium content. This is partly because milk contains somewhat more calcium than phosphorus, and partly because "yeast foods" are chiefly calcium salts other than phosphates.

These statements are based on determinations of oxalic acid in many specimens and by several investigators, while the direct experimentation upon calcium utilization has been chiefly with (1) spinach, (2) loose-leaf lettuce, and (3) kale and Chinese cabbage, as respectively representing the three botanical families whose leaves are most used as human food.

Upon bringing together the evidence of several investigations it is seen to be established by well-controlled experiments that the calcium of celery cabbage, Chinese cabbage, collards, kale, leeks, lettuce, rutabaga leaves, tendergreen, and turnip tops, like that of milk, is well utilized in nutri-

tion; while that of spinach and New Zealand spinach is utilized very poorly if at all.

Recent years have seen great scientific interest and research activity in the nutritional functions and values of the calcium and phosphorus compounds of foods with significant results in two different directions: (1) it has become possible to discuss these elements much more fully than most others; and (2) the experimental evidence reveals complexities and individual physiological variations which warn us against generalizations from small numbers of experiments. Thus in compiling data on the calcium requirement of adult maintenance we include balance experiments with widely different diets; but if any attempt were made to use these same experiments as evidence regarding the availability of the calcium of different foods, the results might very probably be misleading because of insufficient numbers of cases on many individual foods.

EXERCISES

1. Calculate the amounts of phosphorus and of calcium in the dietaries planned under Exercises 2 and 3 of Chapter V.
2. Would either more phosphorus or more calcium be desirable in either of these dietaries?
3. Tabulate the calcium content (*a*) per 100 grams, (*b*) per 100 Calories, for each of the forty foods of Exercise 2 of Chapter IV.
4. If you wish to increase the calcium content of one of the dietaries you have planned, can it better be done by changing the proportions of foods it already contains, or by substituting for one or more of these foods others which you could now select from among the forty foods of the preceding Exercise?
5. Would you substitute "gram for gram" or "calorie for calorie," and why?

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Chapter IX

IRON AND THE NUTRITION OF THE BLOOD

Small as is the amount of iron in the body, its functions are very vital. The chromatin substance of the nucleus of every cell is an iron-protein compound, and so is the hemoglobin which constitutes the outstanding material of the red blood cells and has the important responsibility of carrying oxygen and assisting in the maintenance of neutrality.

There is a considerable concentration of the body's iron in its blood, for while the blood usually constitutes about 7 per cent of the body weight it contains nearer 70 per cent of the body iron. Hence any considerable shortage of iron in the body results before long in some kind or degree of anemia. Iron constitutes one-third of one per cent of the hemoglobin molecule, and hemoglobin is the main solid constituent of the red blood cell.

Thus the study of iron in nutrition is intimately interwoven with the problems of hemoglobin formation and regeneration, the building of the red cells of the blood, and the cure and prevention of anemia. Here, as throughout this book, we are interested in the relations of food and nutrition to health, but we are leaving medical problems to the physician.

While an iron-poor body tends to be anemic, it is important to keep clearly and constantly in mind that shortage of iron is not the only cause of anemia. And even an anemia curable by iron does not necessarily owe its origin to a shortage of iron in the food. The building and upkeep of the blood

is a complex process: it requires iron as an essential element; but it requires also other things, and right conditions.

Copper, while not entering into the constitution of the hemoglobin molecule, exercises an essential influence upon the synthesis of hemoglobin. Thus there is the possibility that hemoglobin formation or regeneration may be retarded by shortage of copper, though under ordinary present-day conditions of life there is strong probability that the accidental intakes of copper will usually be ample for the body's needs.

Life-cycle of red blood cell.—The red cells of the blood are conceived as being formed in the bone marrow, circulating in the blood for an average life-time estimated by different investigators at from 40 to 100 days, and finally undergoing fragmentation either in the general blood-stream or in the spleen. The wearing-out of the individual red cell or corpuscle involves the breakdown of the *stroma* or containing-structure, and also of many of the hemoglobin molecules. The main non-protein parts into which hemoglobin is broken down are: (1) the pigment, bilirubin, which is then carried to the liver and excreted in the bile, and (2) iron compounds which may be used again in the formation of new hemoglobin. It was the interest in this re-using of the iron which gave rise to the term hemoglobin regeneration. This term gained such currency that we now sometimes meet it in scientific literature in connections which seem to indicate that the writers have used it without discrimination as to whether a real regeneration or a new formation of hemoglobin is actually involved.

Anemia

The term *anemia* usually indicates a condition in which the blood is deficient (below normal) in hemoglobin, or in red corpuscles, or in both. Classifications of anemia vary, some being based on the change in the blood picture, and some on the cause of the departure from the normal. On the latter plan, Haden classifies the chief causes of anemia as follows:

I. Increased blood loss
   (*a*) Mechanical loss, hemorrhage (discussed below).
   (*b*) Increased destruction of blood in the body, as in certain familial abnormalities, in some infections, and under the influence of some toxic substances.

II. Depressed blood formation
   (*a*) Depressed bone marrow function, as in nephritis, tumors of the bone marrow, some infections, and the toxic effects of some deleterious substances.
   (*b*) Deficiency of specific substances
      (1) Hypochromic anemia type in which the lack is of some substance or substances required for hemoglobin formation.
      (2) Pernicious anemia type, having to do with depressed formation of the body or stroma of the red cell rather than its hemoglobin.

The fact that a shortage of iron in the food results, if long continued, in anemia, does *not* mean that the majority of cases of anemia are to be attributed to shortage of dietary iron. On the contrary, of the five chief types of anemia recognized in Haden's classification, only one type and only a part of the cases in that, can be regarded as due to iron deficiency in the ordinary nutritional sense. Only a minority (and perhaps only a small minority) of the cases of anemia encountered can be explained on the simple ground that the food was iron-poor. And the fact that administration of iron is helpful does not prove that the anemia occurred because of iron-poor food. For, when iron is given therapeutically, the dosage is usually so many times greater than the iron content of a good average diet that the iron therapy has more of a pharmacodynamic than of a normal nutritional aspect. In other words the prevalence of anemia is more a medical problem than a simple problem of food supply.

Nutrition in the broader sense is of course involved in all such processes as hemoglobin formation and regeneration and in the building of the stroma of the corpuscles, so that in this sense recovery from anemia is largely a nutritional problem whether or not the anemia occurred because of any nutritional deficiency of the food.

Correspondingly we find that experimental studies of anemic conditions have added to our knowledge of nutrition, and have even been utilized as a means of evaluating an aspect of the nutritive value of foods.

Three distinct types of anemia (hemorrhagic, pernicious, and iron-deficiency) have thus figured somewhat prominently in the recent literature of nutrition and should be very carefully distinguished; for undiscriminating statements regarding nutritional anemia and its cure by foods may be very misleading.

Hemorrhagic anemia.—The word hemorrhage tends to suggest a sudden large loss of blood, but it is to be remembered that there may be unseen gradual losses of blood, for example, through the wall of the alimentary tract, which if persistent become significant.

A large loss of blood at one time obviously first reduces the volume in circulation. The volume, however, is rapidly restored by the absorption into the blood stream of fluid from the tissues, with corresponding dilution of the blood both as regards the concentration of red cells and of their hemoglobin. Then, in the regeneration of blood after hemorrhage, new red cells are formed more rapidly than is hemoglobin, so that the red cell count becomes normal earlier than does the concentration of hemoglobin and the depth of red color. In this state the blood is said to have *a low color index*. (Numerically expressed, the color index is the quotient resulting from the division of hemoglobin-in-percentage-of-the-normal *by* number-of-red-cells-in-percentage-of-the-normal.) This condition of low color index (greater paucity of hemoglobin than of erythrocytes) is quite simi-

lar whether it results from a single large loss of blood or from the chronic loss of small amounts.

In the rebuilding of the blood to normal after anemia has resulted from hemorrhage, the problem usually seems, therefore, to center in the question of inducing restoration of the hemoglobin; but to take it as *simply* a hemoglobin problem may be misleading. For hemorrhage depletes the blood of all its characteristic constituents, and while the body usually restores the others more rapidly, thus leaving hemoglobin as the limiting factor in the regeneration, the extent to which this is true may depend very largely upon the body-stores of the individual as determined by the previous nutritional history, and perhaps still more largely upon the nature of the dietary during the period in which the rebuilding of the blood is being observed. Whipple, who has experimented very extensively and systematically with hemorrhagic anemia in dogs, early recognized the importance of both these latter factors. To control individual variations, he keeps his animals under continuous laboratory-sanitarium care and observation between as well as during the experimental periods; and to prevent unknown influences entering through the food, Whipple has long used a basal diet which he worked out and standardized for this purpose. This feature is of great value in giving precision and validity to his comparisons of different "experimental variables" tested as additions to the standard basal dietary. The reader, however, in interpreting this and other work, should keep constantly in mind the fact that if some other basal diet had been just as carefully devised and systematically employed it might have given the findings a somewhat different aspect throughout.

Critical interpretation may appropriately be emphasized here because it is of special importance to one who would read understandingly the anemia literature of the recent and present period of simultaneously rapid developments in research upon different types of anemia; especially the nutritionally very different, though somewhat overlapping, conditions of (1) hemorrhagic

anemia, (2) anemia induced by iron-poor food, and (3) pernicious anemia. Here as elsewhere in science the critical interpretation enjoined upon the reader does not mean a fault-finding bias against what has been recorded but rather that the reader maintain a rigorous attitude toward his own mental processes as he reads and reflects. Assuming that we find no fault with the outstanding investigations on the three types of anemia just mentioned, we have still to demand of ourselves the highest and most rigorous degree of thoroughness and scientific acumen of which we are capable in the thinking through, and the fitting together in our own minds, of the contributions which have come (and apparently are still coming) simultaneously from these largely independent but somewhat overlapping three fields of nutritional research in anemia.

Experimentation has been well characterized as putting questions to Nature. The experimental *data* are then accepted as the answers which Nature *gives* to the questions which the investigator has asked by means of his experiments. One writer has said that clarity of scientific thought would be advanced if instead of "data" ("givens") we could use some such word as "takens" as the conventional label for experimental evidence, because what we find depends largely on the way in which we look (investigate), so that to a larger extent than the uncritical reader usually realizes, experimental findings are partial and selective depending upon the plan and method of the research which reveals them.

Thus in the matter here under consideration, hemorrhagic anemia, iron-deficiency anemia, and pernicious anemia are all in a sense nutritional; but if it be asked how any given foods compare as to value in nutritional anemia, the answer must depend upon the type of anemia in question. The value of any food-supplement in the Whipple type of hemorrhagic anemia is its value as a source of what is most needed to make good the difference between what has been removed from the body by hemorrhage and what the basal experimental diet supplies; while in the second type of anemia the value will depend more specifically upon iron (or iron and copper); and in the pernicious anemia type the nutritional need is not for iron or copper, and may or may not overlap the need of the hemorrhagic type but certainly is not identical with it. For, as already briefly mentioned, hemoglobin

is usually the limiting factor in the rebuilding of blood after hemorrhage, while the building of the red cell stroma is usually the limiting factor in pernicious anemia.

Here again we must be on guard against over-simplification. We have just spoken as if the nutritional need for the rebuilding of good red cells could be stated in terms of materials to enter into their structure; but obviously it is also to be remembered that the blood-building tissues may be amenable to (may even be in need of) stimulation to increased activity. So that what is nutritionally needed may be either a building-stone or a stimulating (activating) substance, or both.

Pernicious anemia.—The type of anemia which was designated as pernicious at a time when it seemed peculiarly resistant, both to therapy and to scientific understanding, has now been largely conquered. Or perhaps we should rather say that it has been largely solved as a scientific problem and the means for the therapeutic conquest of individual cases as they arise are now available and widely understood. The blood picture in pernicious anemia is mainly that of deficient formation of red cells, these being usually subnormal in number and often undersized and irregularly shaped. Moreover, the sufferer from pernicious anemia characteristically shows deficient gastric secretion. Through the researches of Castle and others an explanation of the specific need in pernicious anemia has been suggested in terms of *two factors*, the *intrinsic* and the *extrinsic*. According to this view the extrinsic factor is furnished by the food (in Castle's experiments by beef), and the intrinsic factor is furnished by a normal gastric juice. These two factors react to form the anti-pernicious anemia substance. The primary cause of a typical case of pernicious anemia is an abnormality of the gastric juice which renders it inadequate as a source of the intrinsic factor, and the remedy consists either in re-establishing the normal functioning of the stomach as a secretory organ or in supplying the anti-pernicious anemia substance in some artificial way. Liver and liver extracts

are largely used for this purpose. Dr. Minot complains that too much publicity has been given to this fact so that too many people have an uncritical impression that liver is of high nutritive value with the result that the consuming public's demand for it makes liver "unduly expensive to those who really need it."* For liver is not a food-crop in itself: its production can only be increased by rearing and slaughtering more animals of which the liver constitutes only a very small part. Hence there is far-reaching value in the recent finding by Dr. Mary S. Rose that for purposes of normal nutrition all the dietary virtues of liver can be supplied as well (or better) by eggs. Eggs *are* a crop in themselves, and their production responds so readily to consumer demand that increased consumption has extremely little effect upon price, and that usually only temporary.

Iron-deficiency anemia.—The anemia familiarly produced in the laboratory by keeping young animals an abnormally long time on a diet of milk alone, has been shown to be due to a deficiency of iron, or copper, or both. If this condition were encountered clinically it would be classified as a *hypochromic* anemia, because it shows a low color index, *i.e.*, a greater deficiency in hemoglobin than in the erythrocyte count. And if the low color index was not obviously secondary to hemorrhage, food-deficiency, or some infective or other toxic condition, the case would be classified as one of *idiopathic hypochromic anemia*.

The usual clinical type of hypochromic anemia is more frequent in women than in children or men, and it responds to iron therapy. But the doses of iron used to effect a cure are usually so many-fold greater than the amounts contained in any ordinary dietary that the success of the iron therapy can not logically be interpreted as indicating that the anemia was due to simple shortage of food-iron. It is thought that the menstrual hemorrhage may perhaps play the dominant part in the origin of these hypochromic

*In and around New York City this price-situation appears at present (1940) to be true of calves' liver but not of beef liver, the latter being still relatively cheap.

anemias of women; and as they appear in some women on the same sort of diet on which other women maintain a normal condition of the blood, the term idiopathic may therefore appropriately carry the suggestion that the woman who is less fortunate in this respect may be the victim of an idiosyncrasy in hemoglobin-economy, either losing more than other women or being slower in rebuilding what has been lost. To the extent that this view is adopted, the question then naturally arises whether "standards" for the iron contents of women's dietaries should be set so high as to provide (if possible) for the idiopathic losses of the few as well as the normal nutritional needs of the many. To attempt to give all dietaries a degree of richness in iron which is far beyond the needs of most people may unduly complicate the planning of diets and the general food supply problem. The policy of leaving idiosyncratic needs (idiopathies) to be treated as individual medical problems is certainly safer in the case of iron than of most other nutritional factors because an iron-poor condition of body declares itself more promptly and unmistakably than perhaps any other nutritional subnormality. Even emaciation may be mistaken for a sedulously cultivated slimness; but anemia is practically unmistakable, and under the conditions of present-day civilization a case of incipient anemia, whether idiopathic or not, is apt to be noted and to receive medical attention before it becomes a significant hazard to health or efficiency.

Iron Requirements in Normal Nutrition

Here as in our other quantitative studies of nutritional needs we shall probably do best to start by asking how much need be metabolized by the healthy adult. Let us first glance at the rate of output of healthy men when fasting, and then take up the experimental evidence as to how much iron must be supplied by the food for the maintenance of approximate equilibrium in the normal adult maintenance metabolism.

Lehmann found that two men, Cetti and Breithaupt,

eliminated 7.3 and 7.7 milligrams of iron per day, respectively, while fasting. Nearly all of this was in the feces; for the chief path of elimination of metabolized iron is through the intestinal wall. In the case of iron, as of protein, one readily suspects that when the body is living on its own substance there may be a greater elimination than there need be on a diet planned for economical use of material.

Stockman fed such a diet to four men and found that, while receiving this, they eliminated 3.7, 6.3, 9.3, and 11.5 milligrams of iron per day, respectively. Von Wendt, serving as his own experimental subject, found his iron output to vary with his diet from 8 to 16 milligrams per day, the largest amount of iron being needed (or sacrificed) when the diet was deficient in calcium. In iron-balance studies by Sherman, three diets differing in various respects, but all composed of ordinary articles of food, furnished 5.7, 6.5, and 7.1 milligrams per day of iron, and on these diets the respective outputs of iron averaged 5.5, 8.7, and 12.6 milligrams per day. Here the metabolism of iron was clearly more economical on a diet of bread and milk than on the other diets tried. This is in accordance with Von Wendt's finding that fairly liberal calcium intake is favorable to the iron economy; but the experimental diets here used differed in other respects as well as in their calcium contents. Later experiments of a different kind by Orten, Smith, and Mendel showed that with calcium as the sole variable, the adequacy of the calcium intake may have an important influence upon the body's use of iron in nutrition. In experiments under extreme conditions it has also been shown that enormously excessive additions of calcium salts to the diet may interfere with the iron economy; but this is a condition not likely to be met in human experience. Much more representative were the British experiments with sheep on quite ordinary low-calcium food supplies, in which it was found that as the sheep continued to lose calcium they also grew anemic (personal communication from Sir John Boyd Orr, Director of the Nutrition Research Institute

at Aberdeen). Much of the work thus far mentioned was of a more or less pioneering character, with somewhat widely varied (though in each case quantitatively controlled) iron intakes.

Two of the more recent investigations—those of Farrar and Goldhamer and of Vahlteich, Funnell, MacLeod, and Rose, respectively—have the merit of combining careful planning in the light of previous experience with a sufficiently low iron intake to put the body to a real test as to its nutritional need.

Farrar and Goldhamer found, with four people, average daily exchanges of 5.2, 7.1, 7.8, and 9.1 milligrams of iron daily. Their careful consideration of the circumstances of each case inclined them to the view that the level of actual need for healthy adult maintenance is, for average people, near the lowest of these figures.

Women served as subjects in the work of Vahlteich, Funnell, MacLeod, and Rose. Here the iron exchanges in the four cases studied averaged 5.7, 6.1, 6.1, and 6.2 milligrams of iron per day, respectively. Such a consistent result from such carefully planned and conducted experiments constitutes strong evidence that about 6 milligrams actually sufficed for the normal maintenance metabolism of these healthy women.

There are, however, also on record several studies of iron metabolism in women which have yielded considerably higher results. In part, these higher findings are the result of either uncontrolled or less rigorously controlled intakes. In iron-balance experiments, as in the nitrogen-balance experiments by means of which one studies the protein metabolism, high intake induces high output; so that output can be taken as an indication of quantitative need in those cases only in which the intake is low enough actually to bring the body to its true minimal level. At higher levels of intake, neither the level of output nor the balance throws any reliable light upon the quantitative question of the maintenance requirement.

It is a mistake to suppose that a negative balance necessarily means an insufficient intake. If the intake is higher than the actual need for maintenance the body is not put to the test of showing by its output how much it really needs. With high intakes the body has a surplus which, so to speak, it is in position to use whimsically: it may, and does, show sometimes minus balance. Such balance experiments at relatively high intakes may show something which the investigator wishes to see; but not maintenance requirement.

Nor can one usually learn much about the maintenance requirement from experiments in which the intake is not uniform from day to day. The drawing of a strictly quantitative interpretation from the data of a balance experiment (or of a collection of such experiments) is a delicate task at best; and, in our opinion, would better not be attempted for experiments or observations whose "data" lack the fundamentally important *datum* of a uniform daily intake. When the intake of a balance experiment is allowed to vary from day to day, even if it is accurately measured, the quantitative interpretation of the output becomes so uncertain that, if attempted, the attempt is all too likely to mislead both the investigator and the reader.

The problem of the maintenance requirement of iron for adults is further complicated by the question, whether (and if so, how) shall the "maintenance" requirement provide for the menstrual blood-loss and its replacement in women? Estimates of the amount of iron leaving the body in the menses vary greatly. The data whose accuracy we feel best able to judge showed about three milligrams of iron in the total monthly blood-loss. Obviously the replacement of three milligrams of body-iron in the course of twenty-eight days would add only about a tenth of a milligram to the daily requirement. But some other observers have published figures for menstrual iron varying up to a maximum severalfold higher. Probably at least two major causes contribute to this disconcertingly large variation in the reported data:

(1) experimental errors, and (2) physiological variations in menstrual blood losses among "ostensibly healthy" women. Among experimental errors the reader who has not had experience in such laboratory work will probably think first of the possibility of incompleteness in the collection of the material; but this is obviously the error against which the observer would be most fully forewarned and on guard, and we are confident that the lowest recorded findings are among those of highest technical accuracy. Probably a larger, much more treacherous, source of experimental error is in fact that the invisible dust of most laboratories is relatively high in iron. With the best of intentions it remains extremely difficult to carry through such a collection of material and determination of iron as is here involved without incurring an error of unknown magnitude from the iron (iron oxide) dust of the laboratory air which has added itself to the iron of the material under investigation,—either directly, or indirectly through materials and utensils handled in the laboratory, or both. Hence to one experienced in the sources of laboratory error in this particular field of investigation, the higher estimates do not command higher confidence than the much lower ones.

Whether physiological variations in the menstrual losses of iron are really as great as the face values of recorded data suggest, and what quantitative allowance for such loss should be made in estimating the average daily iron requirements of healthy women, are, therefore, questions which at present can not be answered with satisfactory accuracy.

Rose, in her *Foundations of Nutrition*, Third Edition (1938), tends to treat the high estimates of menstrual losses and of pregnancy requirements as cumulative considerations suggesting a generous degree of liberality in iron allowances for women. Strauss of the Harvard Medical School recommends the *regular* inclusion of iron salt in the dietaries of pregnant women; and it may prove wise to extend this provision to such other women also as may appear to their physicians to have (for any known, or even unknown,

reason) a requirement for more iron than a "good average" dietary will regularly supply.

We have seen, in the brief sketch of the anemias given earlier in this chapter, that idiopathic hypochromic anemia may be somewhat frequent among women. Such cases should be quite practicable of diagnosis by the "nutrition-conscious" physician, and when found may perhaps better be provided for by a regular daily allowance of iron salt than by trying to provide a high iron intake through food selection.

For an attempt at great enrichment of the iron content of the diet through food selection may distort the dietary or the food budget by the inclusion of an undue proportion either of fibrous or of expensive food materials.

Iron in the Nutrition of Children

The normal child is born with a considerable store of reserve-iron in the body. Undoubtedly this endowment at birth is of value to the baby's prospect of survival, of healthy development, and of having a healthy and vigorous progeny in its turn.

Or, in a different way of speaking, it is "more efficient and safer" to transfer this iron to the baby through the mother's placenta than through her mammary glands in lactation. For, while milk contains iron, and in favorable conditions the milk iron is well utilized, still there are certain (and possibly also some uncertain) digestive hazards which are avoided or minimized by the advantage which the newborn baby enjoys of having enough iron already stored in his body to meet the iron-requirements of his normal development for perhaps six months if he absorbed no iron from his food, or perhaps a year when he absorbs a normal proportion of the rather small amount of iron which milk contains.

Both the reserve iron stored in the body before birth and the food iron absorbed by the baby are largely used in the building of hemoglobin. Even so, if the baby grows rapidly

his body size may, and in the majority of cases does, increase somewhat faster than the total body hemoglobin, with the result that the child goes through a period of what is oddly called "physiological anemia." More clearly stated, such a child is in a normal (physiological) phase of his development and need not (should not) be considered anemic even if his hemoglobin percentage is lower than at other ages, or perhaps than in more slowly growing children of the same age.

"Standards" for Iron Content of Dietaries or Food Supplies

Dr. Mary S. Rose recommends 0.5 milligram of iron per 100 Calories of food in family food supplies. This is a generous allowance and follows the same principle as in setting the "standard" for protein as 10 to 15 per cent of the total calories. That is, for children as compared with adults, it provides the same degree of liberality of intake of the building materials as of energy per unit of body weight. The child getting, say, twice as many calories per kilogram, gets also twice as much protein and iron per kilogram as its parents.

This general plan is probably better than the setting up of a series of "standards" of iron intakes for different ages and sizes. But the allowance of 0.5 milligram per 100 Calories is perhaps somewhat disproportionately generous. With the expectation that idiosyncratic needs will receive individual attention as they appear, it would seem ample to set family and general population allowances for food iron at 0.4 milligram per 100 Calories.

The foregoing dietary standards or allowances for food iron do *not* need general upward revision because of recent and current findings indicative of low "availability" or "utilization" of the iron of everyday foods, because it is upon iron-balance experiments with just such everyday foods that the dietary standards of the past thirty years have been based.

Iron and Copper in Foods

Little weight can be attached to such statements regarding the iron content of foods as were based upon the data obtainable from the ordinary tables of ash analyses of the past, as these were usually obtained by methods which are likely to overestimate greatly the amount of iron. More recently, other methods of estimating iron have come into use which are liable to large laboratory errors in both directions. Data for iron contents of foods given in this book are averages of data critically compiled from many sources, so as to minimize individual errors. Table 10 shows the approximate amounts of iron now believed to be present in the average edible portion of typical food materials expressed (1) in milligrams per 100 grams of edible material, (2) in milligrams per 100 grams of protein, and (3) in milligrams per 3000 Calories.

Percentages of iron in many other foods will be found in the Appendix.

Estimates of the amounts of iron contained in many American family food supplies have been made. The majority of these were found to furnish about 15 to 20 milligrams of iron per "man" or "consumption unit" per day. Apparently, therefore, the typical American dietary contains a much better surplus of iron than of calcium, yet not so great a surplus as would justify leaving the supply of iron entirely to chance; hence the following comments upon different articles or types of food as sources of iron (and copper).

Meats.—In ordinary muscle meats the iron exists chiefly as hemoglobin, belonging in part to the muscle cells and in part to retained blood. Since fatty tissue contains much less iron, the iron content of fat meat is much lower than that of lean, and in order to establish a useful general estimate of the amount of iron in meat it seems best to refer the iron to the protein content rather than to the gross weight of the meat. The results will still be influenced by the extent to which the blood has been either accidentally or intentionally removed from the muscle.

TABLE 10.—IRON IN TYPICAL FOOD MATERIALS

FOOD	IRON PER 100 GRAMS FRESH SUBSTANCE	IRON PER 100 GRAMS PROTEIN	IRON PER 3000 CALORIES
	milligrams	*milligrams*	*milligrams*
Beef, all lean.........	3.0[a]	13	80[a]
Beefsteak, medium fat	2.0[a]	13	43[a]
Eggs................	3.13	23	64
Egg yolk............	8.6	53	72
Milk, whole..........	0.24	7	10
Milk, skimmed.......	0.25	7	20
Cheese..............	1.3	5	9
Oatmeal.............	4.8	30	36
Rice, polished........	0.9	11	8
White flour..........	1.0	9	8
Wheat, entire grain...	5.0	45	42
Beans, dried.........	10.5	47	91
Beans, string, fresh...	1.16	48	82
Beets................	0.85	54	55
Cabbage, headed.....	0.43	31	45
Carrots..............	0.64	53	43
Kale.................	2.54	65	152
Peas, dried..........	5.7	23	48
Potatoes............	1.02	52	37
Spinach.............	2.55	111	310
Turnips.............	0.52	47	46
Apples..............	0.36	94	18
Bananas.............	0.64	56	20
Oranges..............	0.36	45	22
Prunes, dried.........	2.85	135	29
Tomatoes............	0.44	49	58

[a]Figures for meats can be only rough approximations because of variations in fatness, as well as differences between different cuts. Forbes and Swift report that organs contain more iron than muscle meats, while pork and lamb contain much less than beef.

For fresh lean beef (containing the usual proportion of blood) the results collected by Sherman averaged 0.00375 per cent iron, but Forbes and Swift (1926) reported considerably lower results, 0.0024 to 0.0025 per cent. Hence, in computing the data for Table 10, a value intermediate between the averages of the two sets of findings has been used.

Some years ago, chiefly as a means of avoiding the serious discrepancies which might otherwise arise from the great variability of meat in fatness, it was suggested that a rough estimate of the amount of iron furnished by the meat of a dietary might be made by assuming that with every 100 grams of protein the meat would furnish about 0.015 gram (15 milligrams) of iron. This estimate Forbes and Swift consider to be "a little high for beef and veal, and much too high for lamb and pork, while it does not apply at all closely in relation to heart, brain, liver, spleen, kidney, and blood". All of these latter are such minor products in comparison with ordinary muscle meats that even if completely utilized as human food their effect would be to raise but slightly the percentage of iron in the meat supply as a whole. Hence it appears from the work of Forbes and Swift that the custom of assuming in dietary calculations that meats furnish about 15 milligrams of iron per 100 grams of protein has somewhat overestimated the value of beef and veal, and much overestimated that of lamb and pork, as sources of iron; but that the use of this factor becomes more nearly correct as products such as liver, spleen, and kidney are being more largely utilized as human food. It should, however, always be kept in mind that any such single factor can serve merely for the discussion of meats as a whole and not for the comparison of one meat with another.

The copper content of beefsteak was found by Lindow, Elvehjem, and Peterson to be about one part in 1,000,000; and other beef products showed very similar figures, except liver, which contained, weight for weight, about twenty times as much copper as muscle tissue.

Eggs.—The edible portion of hens' eggs has shown as the average of several analyses almost exactly 0.003 per cent of iron. Whether the iron content of eggs can be increased by giving to poultry food rich in iron, is a disputed question. It seems probable that both the relatively high iron content of the egg and its copper content of about two parts per

million are properties rather definitely fixed by nature. In experiments at the University of Wisconsin the iron and copper contents of eggs remained unchanged when the diet of the hen was enriched with added iron, or copper, or both.

There would seem to be no room for doubt regarding the assimilation and utilization of the iron compounds of eggs, since they serve for the production of all the iron-containing substances of the blood and tissues of the chick, there being no introduction of iron from without during incubation. Iron-balance experiments with young women have shown that the iron of egg is also highly efficient in human nutrition. As already noted, Dr. Mary S. Rose considers eggs in all respects equal to liver in normal nutrition.

Milk.—Analyses of samples of cows' milk of widely different origin have given results varying both with the milk and with the analyst, and averaging about 0.0002 per cent of iron in the fresh substance.

The iron of milk is readily absorbed and assimilated. Moreover, metabolism experiments indicate that the iron of milk is likely to be utilized to especially good advantage, perhaps on account of its association with a liberal (but not excessive) proportion of calcium, and with other materials of high body building value.

According to work at the University of Wisconsin, milk contains only 0.000015 per cent of copper, and neither the iron nor the copper content of milk is much influenced by the feeding of iron or copper salts, or both, in addition to the normal ration of the cow. Thus milk is apparently rather well stabilized by nature in the matter of its calcium, phosphorus, iron, and copper contents. The fact that the Wisconsin workers find a higher copper content in calves' liver than in beef liver may perhaps be taken as an indication that the body of the young mammal is thus provided with a reserve store of copper as well as of iron at birth.

Grain products.—Iron occurs in considerable quantity in the cereal grains, but the greater part of it is in the germ

and outer layers, and so is rejected in the making of the "finer" mill products, such as patent flour, polished rice, and new-process corn meal. To test the value of the iron in the outer layers of the grain, Bunge several years ago carried out the following experiment:

A litter of eight rats was divided into two groups of four each. One group was fed upon bread from fine flour, the other upon bread made from flour including the bran. At the end of the fifth, sixth, eighth, and ninth weeks, respectively, one rat of each group was killed, and the gain in weight, the total amount of hemoglobin, and the percentage of hemoglobin in the entire body were determined.

Here the bran-fed rats not only made a much greater general growth, but developed both a greater amount and a higher percentage of hemoglobin. There can be no doubt that the iron and other ash constituents of the outer layers of the wheat were well utilized in these cases.

The recent work of M. S. Rose and her collaborators also shows clearly the good utilization of the iron of whole wheat in hemoglobin formation as tested with rats; and the high efficiency of the iron of whole wheat in human nutrition as measured in balance experiments with young women.

Fruits and fresh vegetables are often regarded as of low nutritive value because of their high water content and low proportions of protein and fat; but largely for this very reason they may be especially important as sources of food iron, because they can be added to the diet without replacing other foods, and without making the total calorie consumption excessive. Present transportation facilities and methods of preserving tend to equalize the cost and increase the available variety of fruits and vegetables throughout the year. Several years ago Von Noorden had found in regard to the feeding of children that:

"The necessity of a generous supply of vegetables and fruits must be particularly emphasized. They are of the greatest importance for the normal development of the body and of all its functions. As far as children are concerned,

we believe we could do better by following the dietary of the most rigid vegetarians than by feeding the children as though they were carnivora. . . . If we limit the most important sources of iron,—the vegetables and the fruits,—we cause a certain sluggishness of blood formation and . . . lack of reserve iron, such as is normally found in the liver, spleen, and bone marrow of healthy, well-nourished individuals." A little later it was found, in an experimental dietary study made in New York City, that a free use of vegetables, whole wheat bread, and the cheaper sorts of fruits resulted in a gain of 30 per cent in the iron content of the diet, while the protein, fuel value, and cost remained practically the same as in the ordinary mixed diet obtained under the same market conditions. Gillett and Rice also found that the general advance of nutrition consciousness and dietary intelligence had similarly improved the typical family food supplies of the New York City poor between 1914-15 and 1928-29. This was found by the use of the data for iron in foods which were available some years ago. Peterson and his coworkers suggested that fruits and vegetables generally may have even higher iron values than hitherto appreciated. This led to a large number of new determinations of iron in fruits and vegetables by Stiebeling, who also computed new general averages for fruits and vegetables which took account of Peterson's and other data as well as her own.

Current Applications and Interpretations

Stiebeling has also estimated the contributions of different articles and types of food toward the total iron values of the dietaries of typical American families, and of community, regional, or national food supplies. Much of this work is still in progress at the time of writing (1940) but a typical finding may be cited as follows:

Stiebeling and Phipard found in the dietaries of a group of 26 East North Central families spending $1.88—$2.49

weekly per capita for food, that fruits and vegetables furnished 34 per cent of the total food iron; meats, including poultry and fish, 29 per cent; grain products, 19 per cent; eggs, 10 per cent; milk and its products, 7 per cent; and miscellaneous items, 1 per cent.

Whether and to what extent the iron of one group of foods has a higher, and that of another group of foods a lower, availability or utilizability in normal nutrition, are, in our opinion, questions which cannot yet be definitely answered. Many recent statements or implications which superficially appear to bear on this question are seen on closer examination to be either of doubtful applicability to the actual problem of normal nutrition, or to give exaggerated impressions. The tendency which some investigators and writers have shown to count the percentage of iron which responds to a certain *in vitro* reagent as a measure of the percentage available in nutrition involves far too much of extrapolation to be defensible in scientific principle and has certainly in some cases been misleading in practice. Another frequent fallacy has been to confuse the availability of the iron in a food with the effect of the food in promoting hemoglobin formation in an anemic animal. We have seen earlier in this chapter that iron is not always the limiting factor in hemoglobin formation, that the different experimental anemias are not interchangeable, and that it is doubtful what bearing the experimental anemia studies have upon the process of blood formation in normal nutrition. The further warning must be added that very conflicting results have been reported by different groups of even experienced investigators notwithstanding the use of supposedly the same experimental method. Thus neither the technique nor the interpretation of such experiments can yet justify confidence. About all that we can see clearly at present is that the methods, both *in vivo* and *in vitro*, recently so much used for studies of supposed differences of availability, give such uncertain results and such exagger-

ated impressions that it is much safer as yet to continue the use of simple average figures of *iron content* as the best approximation to the relative *iron values* of foods.

The figures for iron contents of foods given in Table 10 and in the Appendix of this book are recent averages which take account of the data of Peterson and of Stiebeling above mentioned, of those used by one of us in previous writings, and in several cases of additional new data from various sources.

These 1939 averages are in a fair proportion of cases, including most of the more important foods, the results of analyses of samples so numerous and from so many sources, that they probably will be relatively little changed by the future accumulation of further data. It remains true, however, that figures for iron are subject to relatively larger probable error than are the corresponding data for calcium and phosphorus. This is partly because the actual percentages of iron in food are so small that the unavoidable errors of the laboratory work of preparing and analyzing the food samples tend to become a larger fraction of the actual value. Probably, too, the methods for quantitative determination of iron are more "treacherous" than those for protein, or phosphorus, or calcium; in the sense that the "personal equation" tends to be relatively larger and more variable in the determinations of iron. For these reasons it is difficult to judge whether or not a given type of food is relatively more variable by nature in its iron than in its protein, phosphorus, or calcium content.

But if our knowledge of iron requirements in nutrition and iron contents of foods is still somewhat sketchy, reassurance is afforded by the important fact that any tendency toward an iron-poor condition of body is apt to be recognized and corrected promptly.

EXERCISES

1. Calculate the iron contents of the dietaries previously planned, and compare with your judgment of the requirements of the people to be fed.

2. What substitutions, preferably from among the forty foods previously tabulated, would enrich one of these dietaries in its iron content without any disadvantageous change in its general character or in its cost?

3. Would it be more practicable to make the proposed substitution weight for weight, or Calorie for Calorie?

4. What is an average medicinal dosage of iron per day? Would it be feasible to provide so much iron through food selection without distorting the dietary or making it unduly costly?

5. Is there, in the light of present-day knowledge, any sound objection to making nutritional use of iron salts, under medical guidance, so as to be freer in planning the best use of the food money?

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Chapter X

IODINE

The Endocrine Glands and Especially the Thyroid

It has now become a concept familiar to almost everyone that the physical and mental development of an individual as well as the course and rate of his metabolic processes are controlled to a large extent by a group of organs known as the *endocrine glands* or the *glands of internal secretion*. Each of these elaborates one or more physiologically active, specific chemical substances, known as *hormones*, which it distributes through the blood stream to the entire body, exerting in this way a "chemical control" over even the most remote parts. When, for some reason, there is either a deficiency or an overabundance of the secretion of one of the endocrine glands, physical or metabolic abnormalities may become evident. Most of these conditions lie outside of the sphere of this book (the student interested in these aspects is referred for a non-technical discussion to Hoskins' *The Tides of Life*); but one such manifestation, the disturbance of the thyroid gland known as simple goiter, has now been shown to be predominantly of nutritional origin and amenable to control by nutritional measures.

The *thyroid gland* is situated near the base of the neck and consists of two lobes, one to each side of the trachea ("wind-pipe"), connected by an *isthmus* lying across the front of the trachea. It is this structure which becomes swollen to give the familiar picture of goiter.

Goiter has been known from time immemorial: references

to it are found in many of the oldest writings, and the works of the old masters attest its prevalence in their times. An Englishman who paid an extended visit to Switzerland and the adjacent parts of France and Italy in the eighteenth century, and whose letters written thence were afterward published, told of the great prevalence of goiter in certain localities. In the part of Savoy where he stayed it was so nearly universal that anyone without goiter was said to be not a true Savoyard. Growth of the goiter was regularly expected to accompany the growth and development of the child. Thus a middle-aged man whose little granddaughter's goiter was the size of a chestnut piously hoped to live to see it as large as a pear.

Even a generation ago there were regions in this country and abroad where some measure of thyroid enlargement was discernible in a large majority of the adolescent children; and today, although recognition of its nutritional origin has made it possible to prevent almost completely the onset of the disorder, advanced goiters are a fairly common sight, at least among middle-aged and elderly persons for whom this knowledge came too late.

Establishment of the Relationship of Iodine to Goiter

It is said that for many centuries burnt sponge was a more or less popular folk remedy for goiter. Medical men, following the suggestion made by Coindet in 1820, found that painting the goiter with tincture of iodine was also frequently efficacious. As the existence of the element iodine had been discovered in burnt seaweed, Coindet postulated that iodine present in the sponge was responsible for the effectiveness of the old treatment. However, the *rationale* of both of these curative measures was fully appreciated only when Baumann, in 1895, actually found iodine in the thyroid gland. This led the way on the one hand to investigations on the natural distribution of iodine and its relation to the incidence of goiter, and on the other hand to Kendall's discovery and separation in pure form of *thyroxine*,

an iodine-containing amino-acid derivative secreted by the thyroid gland (Fig. 21).

There are certain regions of the earth where—until modern preventive methods were introduced—goiter occurred so persistently and so extensively as to be called *endemic*. Notable among these districts were the Himalayan Mountain region of South Central Asia; the Alps, Pyrenees, and Carpathian Mountain regions of Europe; the Andean plateau and southeastern Brazil in South America; and the

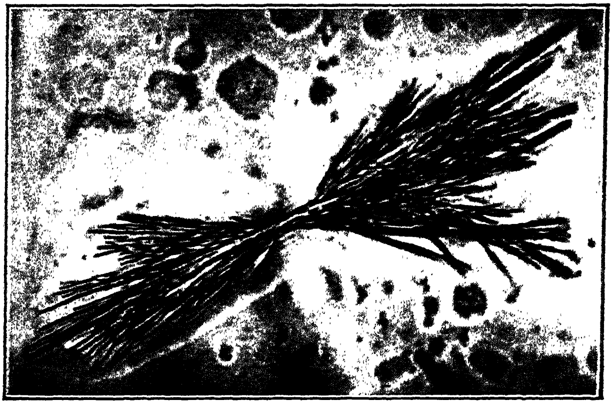

FIG. 21. Crystals of thyroxine. (*Courtesy of Dr. E. C. Kendall.*)

St. Lawrence and Great Lakes basin, extending through northern Ohio, Michigan, Minnesota, the Dakotas, and adjacent Canadian provinces; and the Pacific Northwest including Oregon, Washington, and British Columbia, in North America.

Examination of the soil, the drinking water, and the vegetation in these regions showed them to be relatively poor in iodine as compared with regions where goiter is not prevalent. The iodine content of the waters and foods of any district seems to depend largely upon the chemical nature of the rocks and the amounts of soluble iodide which these yield in their natural weathering. In general, the leached soils deposited from the last glacial period are said to be poor in iodine. Such soils account for the low iodine

content in certain of the goitrous regions of this continent. Furthermore, since seawater, and therefore the spray which evaporates in the air at the seashore, is relatively rich in iodine, regions near the ocean and not separated from it by high mountains receive iodide from sea-spray dust carried inland by the winds. No doubt the relative influence of rocks and sea upon the iodine content of the soil and of the drinking water varies considerably in different regions. That the resulting differences may be very great is illustrated by the finding of McClendon and his coworkers that drinking waters from different parts of the United States ranged in their content of iodine from 0.01 to 73.30 parts per 1,000,000,000—seven thousand times as much in the maximum case as in the nine minimum cases.

McClendon also showed that differences in the relative frequency of goiter among men drafted from various parts of the country for service in the World War were strikingly associated with differences in the amounts of iodine found in the drinking waters in the regions from which the recruits were drawn, goiter being very much more common in sections where the water supplied relatively little iodine.

Similarly it was found that foods produced in the regions characterized as goitrous contain in general distinctly less iodine than the same foods from the so-called non-goitrous districts. A few instances are cited in Table 11.

TABLE 11.—IODINE CONTENTS OF FOODS FROM GOITROUS AND NON-GOITROUS REGIONS

KIND OF FOOD	FROM GOITROUS REGIONS	FROM NON-GOITROUS REGIONS
	Iodine: parts per billion of dry matter	
Wheat	1–6	4–9
Oats	10	23–175
Carrots	2	170
Potatoes	85	226
Milk	265–322	572

It is still difficult to judge how far the differences in iodine contents of foods have been exaggerated by analytical errors. The example which McClendon has selected for prominence in his 1939 monograph shows 111 parts per billion of iodine in the cabbage grown in eastern Minnesota where the goiter rate is 1.72 per cent, and 174 parts per billion of iodine in that grown in the western part of the same state where the goiter rate is 0.85 per cent. Here there was presumably a maximum of scientific control, and a minimum of analytical error.

Observations such as those which have been cited, associating a low intake of iodine in food and drink by a section of the population with a high tendency to goiter, strongly suggested that the former circumstance might be the predominant factor in the causation of the latter. Further evidence of the relationship was afforded when McClendon and Williams in 1923 produced goiter experimentally in rats by a diet low in iodine, fed under conditions of laboratory control.

Apparently, the increase in size of the gland is the result of an effort on the part of the thyroid to compensate for a shortage of iodine from which to synthesize its hormone(s) (thyroglobulin and/or thyroxine), by increasing the number of secreting cells and the volume of fluid secreted.

Simple Goiter Prevented by Adequate Iodine Intake

The now classical experiment of Marine and Kimball demonstrated that *simple goiter*, in most if not all cases, is a *deficiency disease* resulting from inadequate dietary intake of the *nutritionally essential* mineral element *iodine* and preventable by a sufficient supply of this food factor. These investigators administered iodine systematically to as many as volunteered of the school children of Akron, Ohio, of the ages at which goiter most commonly appears. The iodine was given as sodium iodide in small doses twice weekly over a period of a month and the treatment repeated twice yearly. The success of this preventive measure was

striking. Of more than 2000 children treated, only 5 developed goiter; while, of a similar number not treated but of the same age and living in the same locality, about 500 showed thyroid enlargement during the same time. In other words, about 99 per cent of the goiters which would otherwise have developed were prevented by the simple administration of sodium iodide.

While the characterization of goiter as the most easily preventable of all diseases is a justifiable aid to memory, it should also be remembered that not all goiters are attributable to shortage of iodine. McCarrison several years ago described a goitrous village in India of which the best explanation appeared to be the infection of the thyroid by contaminated drinking water; and in a recent Canadian report*, abstracted in the *Journal of the American Medical Association*, infected water rather than shortage of iodine was thought to be the chief cause of the goiters found locally in Saskatoon. That local epidemics and sporadic cases of goiters due to infection may occasionally be encountered should be frankly recognized; but should not blur the established fact that in typical regions of endemic goiter the incidence of this disease has been enormously reduced by simply supplying iodide in drinking water or in table salt. The reduction of incidence in school children by 85 per cent in three Swiss cantons and still more in the Ohio city already referred to may presumably be taken as fairly representative of the efficacy of these methods of iodide supply.

Thus it is probably a fair generalization that nearly 99 per cent of the simple goiters of goitrous regions are attributable to iodine deficiency and are preventable by the regular use of iodide in drinking waters or (more simply) iodized salt in the households of all the people.

In large cities, or over large areas, where the use of iodized salt has been advocated by health officers but without

*Binning, C. 1939 *Canadian Public Health J.* 30, 393–399.

means of making it universal, subsequent surveys have shown greatly reduced goiter-incidence in the families using iodized salt as compared with next-door neighbors who did not.

Incidentally, it has been observed by medical schools in Great Lakes cities, that even stray dogs living largely on garbage get therefrom the benefit of the use of iodized salt in so many households that it is now quite difficult to find a stray dog with a goiter, whereas formerly the stray dogs of these cities were commonly goitrous.

Thus, according to a widely quoted statement of Dr. David Marine, goiter is "the simplest, the easiest, and the cheapest of all known diseases to prevent."

The Body's Need for Iodine

Evidently, the body has a rather definite nutritive requirement for iodine which must be met if the thyroid gland, one of the most important regulators of body processes, is to function normally. When the supply of iodine is only moderately deficient, the thyroid gland may become enlarged to form a goiter and yet be able to provide the thyroid hormone in normal or nearly normal quantities, so that the individual continues to enjoy fairly good health. But in severe iodine deprivation, despite the compensatory enlargement and increased activity of the gland, a deficit of the thyroid hormone exists and may cause the profound disturbances in physical and mental well-being and development known as *myxedema*. The edema from which this disease takes its name is well illustrated in the accompanying Fig. 22. Another characteristic feature of this condition is a markedly lowered rate of energy metabolism, the chemical processes of the body upon which growth and function depend being stepped down, sometimes to half the normal rate. Correspondingly, the victim is exceedingly sensitive to the cold; suffers from flabbiness and weakness of the muscles, tiring easily on slight exertion; and his mental processes become progressively more sluggish. These symp-

toms are often dramatically relieved when thyroxine is administered.

Iodine deficiency in childhood may markedly stunt the growth in height. Here also the cure due to thyroxine and the change in general appearance are frequently striking, as in the case of the girl shown in Fig. 23.

Qualitatively, the requirement for iodine might be stated as a sufficient amount of iodine to meet the daily losses from

FIG. 22. Photographs of a young woman before and after the cure of myxedema by thyroxine. Besides the disappearance of the edema, note the increased mental alertness evident in the second photograph. (*Courtesy of Dr. E. C. Kendall.*)

the body and maintain within the body such store as is needed to provide for the manufacture in the thyroid gland and the distribution throughout the body of sufficient amounts of thyroid hormone to support a normal rate of physiological activity, without the gland becoming abnormally enlarged.

It is estimated that the body of a full-grown healthy man contains in all about 25 milligrams of iodine; or, roughly, about 1 part of iodine in 2,800,000 parts of body substance. About three-fifths of this is found in the thyroid gland. The body iodine occurs in part as inorganic iodide

and in part in organic combination as thyroxine, thyroglobulin, di-iodotyrosine, and possibly other forms. How much iodine must be taken in daily to maintain this store of iodine in the body, cannot be stated with assurance. Attempts to determine the minimum requirement by balance experiments of the type applied to calcium, phosphorus, and iron have been so few, and attended by such great practical difficulties, that conclusions based on them must be regarded as only tentative. From such a study, von

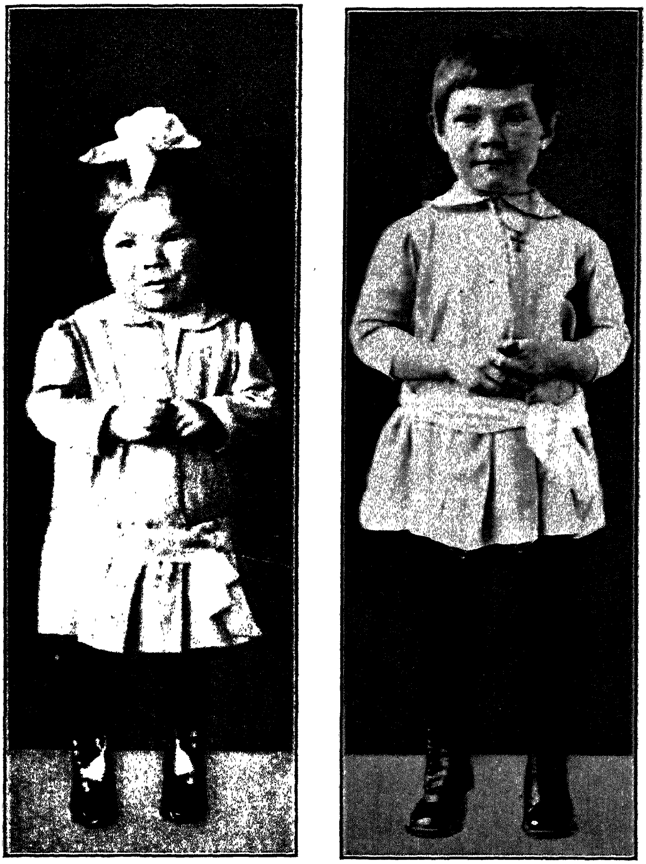

FIG. 23. Restoration of growth in a girl upon treatment with thyroxine. The two photographs were taken in the same dress at an interval of six months. (*Courtesy of Dr. E. C. Kendall.*)

Fellenberg estimates that the normal human adult requires about 0.000014 gram (14 micrograms) of iodine daily.

The need for iodine is considerably increased during growth (as illustrated by an eight and one-half year old child who, according to von Fellenberg, required about 50 micrograms); and is most marked at the time of puberty. This latter fact explains the especially great susceptibility to goiter during adolescence. Pregnancy also brings demands for additional iodine and, unless these are met, the tragic condition of infantile myxedema may result in the baby.

When amounts of iodine in excess of the minimal requirement are furnished by the food and drink, an easily mobilized reserve store of iodine is built up in the body. This capacity for storing iodine undoubtedly explains how, in the experiments of Marine and Kimball, the protective effect of a period of intensive iodide dosage extended through five succeeding months when no supplementary iodide was given.

How May the Needed Iodine be Supplied?

With the exception of seafoods, which are consistently rich sources of iodine, most foods are too variable in their iodine content to be depended upon to meet the dietary need for this element. It is true that many foods grown in the so-called non-goitrous regions are rich enough in iodine that their use might supply the whole or a significant part of the nutritive requirement. But in these regions generally the drinking water also shows a relatively high iodine content, often much more than enough to satisfy body demands. Whereas in the goitrous regions, where the drinking water is comparatively poor in iodine and there is consequently greater need to supply this element from other sources, the native plant products may contain only a fraction of the iodine present in the same plants grown in non-goitrous sections!

(It should be emphasized strongly that iodine is an exception—or, at any rate, an extreme case—among the mineral

elements with regard to the relatively large variations in the concentration in which it may occur naturally in the same type of plant.)

Thus, while in normal regions the drinking water and natural food products provide the iodine required for the proper functioning of the body, reliance cannot be placed on either of these sources in districts where goiter is known to be prevalent. To prevent this disorder and promote normal nutrition in such regions, it was necessary to find a means of insuring a supplementary intake of iodine by every individual in the community. With this aim, a small amount (one part in 5000 to 200,000) of sodium or potassium iodide is now being incorporated in the table salt marketed in those sections of the country where goiter was formerly common.

The efficacy of this "iodized salt" as a goiter preventive has now been well established by experience. For the individual in whom the disease already exists, however, the problem of treatment lies in the realm of medicine rather than of nutrition. Indeed, there are certain goitrous conditions in which increased iodine intake may be actually injurious. However, there appear to be few grounds for the fear that normal individuals, either by the use of iodized salt or through food or drink of naturally high iodine content, may receive too much iodine for optimal health. And the iodide added to table salt should be regarded, not as a drug, but as restoring the table salt to something more like its natural composition; for sea salt and crude salt obtained from salt wells contain iodine, and the modern highly artificial refining processes which remove this iodine have in a sense "denatured" the salt.

EXERCISES

1. Obtain from the United States Public Health Service their most recent available evidence as to the prevalence of goiter in different regions. Is the region in which you live relatively goitrous or relatively free from goiter?

2. Can you explain the prevalence or rarity of goiter in your

region by reference to (a) relation to the sea, (b) relation to th geological formation, (c) food habits of the people, (d) use o iodized salt?

3. What proportion of iodide to chloride in salt for househol use is advised by (a) the Federal government through the Publi Health Service or the Food and Drug Administration, or both (b) your State or City Health Officer, (c) your family physician?

4. Within what limits do you yourself consider that salt ma be iodized to be both effective in the prevention of goiter and saf for general use?

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Chapter XI

ASCORBIC ACID (VITAMIN C)

The Former Prevalence of Scurvy and the Discovery and Identification of the Antiscorbutic Substance

So little did fresh fruits and vegetables figure in the food supply of Northern and Central Europe a few centuries ago, that when Catherine of Aragon came to England it was necessary for the household of Henry VIII to send abroad to get the materials for a salad. And during the period (and in the regions) in which these foods were so scarce for so much of the year, scurvy was so prevalent that medical writers seriously discussed the suggestion that all diseases be regarded as outgrowths of scurvy.

European medical literature, however, has so short a history that we do not know for how long scurvy had been such a scourge: it is known to have afflicted the Crusaders in the thirteenth century, and near the end of the fifteenth century when Vasco da Gama made his historic voyage around the Cape of Good Hope, he reported the death by scurvy of 100 men out of his crew of 160.

The formal medical name for scurvy is *scorbutus;* and things capable of preventing scurvy are often called *antiscorbutics*. Gradually it was learned that this antiscorbutic property is manifested by many "fresh" parts of plants.

In 1535, when Cartier was obliged to winter in Canada on his second voyage to Newfoundland, scurvy killed a quarter of his men. Nearly all the others were severely ill with it, but on advice of the natives a remedy was found

in decoctions of the twigs and needles of evergreen trees. Recent investigations of Russian government bureaux interested in the settlement of northern Siberia indicate that leaves and twigs of both pines and spruces may be thus utilized as antiscorbutics. Tolstoy tells in *War and Peace* of the long-standing habit of the Russian peasants to scour the country in early spring, hunting for and devouring practically everything green and freshly growing.

Returning to the history of the exploration and settlement of America, we find that, in provisioning for regions which did not afford fresh fruits, thought turned first to wine as a substitute and then to beer as a substitute for wine. And crude, freshly fermenting beer was more or less generally recognized as antiscorbutic. Dr. John Nichols of Washington writes us (personal letter of 1938) of early New England records which show that shipmasters who brought colonists were careful to make sure that there be someone on board who could look after the malting of barley and the brewing and care of the beer. John Alden, whose name has been immortalized in literary romance, was, Dr. Nichols finds, first enlisted primarily as a cooper to have charge of the brewing equipment and the beer barrels. The malting process is, of course, merely a carefully regulated sprouting of the barley grain, which, like other seeds, is not antiscorbutic in the "resting" state but develops the antiscorbutic property as it sprouts. The simultaneous enzyme activity, changing starch to maltose, provides material for the fermentation. Thus a freshly fermenting infusion of (unroasted) malt has the antiscorbutic property of sprouting seeds; but *present-day* beer is so highly clarified that all antiscorbutic (and practically all other vitamin value) is lost.

Lind of the British navy described in his *Treatise on Scurvy* (1757) the treatment of an outbreak of scurvy on shipboard in 1747 under conditions which gave his experience much of the definiteness of a laboratory experiment. He took 12 patients (of the crew of the *Salisbury*) who appeared to be equally scorbutic and treated two by each of

six regimes then more or less currently recommended. The two who received the limited amount of oranges and lemons available made dramatic recoveries.

In 1841 the American physician Budd advanced from the concept of an antiscorbutic property possessed by certain foods to the explicit postulate of a definite individual substance (chemical "element" in the terminology of his day), which he predicted would be identified "in a not too distant future." And in 1931–32, King, of the University of Pittsburgh, first effected the chemical identification of the antiscorbutic substance (Fig. 24). His identification was quickly confirmed, and within a short time the substance had been synthesized by more than one method.

FIG. 24. Crystals of ascorbic acid (vitamin C). (*Courtesy of Dr. C. G. King.*)

During the ninety years between Budd's prediction and its fulfillment by King, much was learned through clinical, field, and laboratory observations.

Government regulations required the carrying of citrus fruit juice by British ships, and its regular issue to all members of the crew on long voyages. This was found to be effective. It also came to be generally recognized that as potato culture had become more common in Europe scurvy had become less common, and correspondingly that the failure of the potato crop in any considerable region meant scurvy in that region the following winter or spring. Thus the failure of the potato crop in Ireland in 1846 was followed both by famine and by a crushing epidemic of scurvy.

In 1906, Hopkins of Cambridge University definitely included scurvy among the diseases due to nutritional deficiency, and in 1907 the Norwegian investigators, Holst and

Frölich, published the first of their researches in this field. The clinical work of Hess and the laboratory work of Mendel and his students followed quickly; and these scientific advances enabled army and navy medical men both largely to prevent scurvy and also to systematize the recording and interpretation of the necessarily fragmentary observations made during the World War. After the war, when increased numbers of scientific workers were able to return to the fundamental problems of the nutrition laboratories, there was a period in which pioneering laboratory work upon several substances of demonstrated nutritional importance was simultaneously very active before the chemical nature of any of these substances could yet be known.

As a temporary expedient to reduce the confusion in the rapidly growing literature, the term *vitamine* which Funk had coined was combined with McCollum's terms *fat-soluble A* and *water-soluble B* to form the new terms *vitamin A* and *vitamin B;* and Drummond, in proposing this system, added the antiscorbutic substance as *vitamin C.*

If the alphabetical sequence of the designations had followed the chronological sequence of what we now regard as clearly postulated nutritional concepts, the ABC order of these three substances would be reversed; for the antiscorbutic substance was explicitly postulated as a chemical individual many years earlier than was the antineuritic substance (vitamin B); and the existence of the latter was apparently known earlier than was that of the fat-soluble substance which came to be called vitamin A.

King and his collaborators worked systematically for years to concentrate and isolate vitamin C as a chemical individual, testing and measuring their progress at each step by quantitative determination of the antiscorbutic potencies of their products. In the early spring of 1932, they had thus completed the physical isolation and chemical identification of the substance investigated as vitamin C. It then became possible to devise methods for its rapid determination, with fair accuracy even in small amounts of

material; and thenceforward its investigation has proceeded rapidly and is still (1939-40) very active.

With vitamin C chemically identified and found to be a relatively simple substance, there yet was difficulty in finding a name of convenient length and satisfactorily indicative of its chemical nature. Hence usage has increasingly adopted the name *ascorbic acid* as being distinctive and as perpetuating the historical association of the substance with scurvy, through the study of which its existence was first postulated and finally proven.

The Nutritional Significance of Vitamin C

In vitro, and presumably in the life processes of plants, the outstanding property of ascorbic acid is that of entering readily into oxidation-reduction reactions. *In human nutrition*, at least equal significance attaches to its function in the formation and maintenance of the intercellular cement substances of the tissues. While most biological teaching tends strongly to emphasize what goes on within the cells, it is just as fundamentally scientific to realize that many of these intracellular activities can proceed normally only on condition that the intercellular cement substance holds the cells in proper relation to each other and to the body fluids which bathe and nourish them.

Wolbach offers, as a result of his pathological research, an impressive array of ways in which body function may be impaired through the effects of shortage of vitamin C upon the integrity of the intercellular material in different bodily organs and tissues:

(1) Hemorrhages, which may occur anywhere in the body, and which are a prominent feature of the classical picture of scurvy. Sometimes the hemorrhages are tiny *petechiae* visible in or through the skin, sometimes crescent-shaped areas at the bases of the teeth, sometimes invisible hemorrhages in the joints, making them stiff and sore. At autopsy, hemorrhages are often found also in the wall of the digestive tract and at the rib junctions.

(2) Structural changes in the gums and teeth, the latter having been considered by some investigators to be the most delicate structurally observable indications of shortage of vitamin C.

(3) Changes in the growing ends of bones, sometimes causing confusion between rickets and scurvy in children.

(4) Defective calcification due to degeneration or lack of proper development of the bone matrix.

(5) Displacement of bones due to weakness of the supporting cartilage.

(6) Anemia due to interference with the functioning of the blood-forming cells in the bone marrow, as well as to the loss of blood by hemorrhage.

(7) Damage to heart muscles, sometimes shown by enlargement of the heart.

(8) Degeneration of muscle structure generally.

(9) Injury to the sex organs.

With shortage of vitamin C constituting the underlying nutritional fault which may show itself in such different ways as these, it is to be expected that constitutional differences among individuals may determine the way in which any one person will suffer from this same sub-optimal feature of food supply.

Hence, even though the symptoms may be somewhat confusingly varied, we may still have a clear impression that vitamin C is a nutritional factor of very far-reaching importance.

It must not be thought that nowadays scurvy exists only in remote places or in the minds of alarmists. No less sane a scientist than Professor Hopkins of Cambridge University has reported an experience which came to his attention in a large school in England. During the winter term at this school the standards of work and play fell to an unsatisfactory level; the boys became listless and irritable, and various minor complaints were reported. Attempts to explain the condition were for some time unsuccessful. At last the suggestion was made that the diet be investigated by some

one with modern knowledge of nutrition. The food conditions had traditionally been considered quite satisfactory. It was found, however, that the diet contained nothing in the way of uncooked foods and practically no green vegetables. A small fruit shop nearby, where the boys had formerly purchased fresh fruit with their pocket money, had been closed for some time. Upon restoring a liberal amount of fresh fruit to the diet the whole trouble disappeared. These school boys had evidently been suffering from incipient scurvy, due to the low intake of vitamin C during the period in which they did not have fruit.

Shortage of vitamin C may begin to be injurious considerably before the classical signs of scurvy appear, and for the reasons indicated above the earliest effects may show considerable individual variation. Hence clear-cut evidence and consensus of opinion as to the incidence of prescurvy or early or incipient effects of sub-optimal intakes of vitamin C are lacking, but there is a strong and still growing conviction that sub-optimal levels are much more frequent than hitherto realized. Thus medical surveys in Canada and in Maine have shown many cases of subacute scurvy which, but for recent research, would probably have gone unrecognized.

King and his coworkers showed that shortage of vitamin C lowered resistance to bacterial toxins, and that this lowered resistance was clearly demonstrable before there was any external evidence of scurvy. They also found that injections of the bacterial toxin caused rapid and marked depletion of vitamin C from the body, especially from its glandular tissues. Obviously, experiments of this latter type could be made only with animals; but methods are being developed for studying such quantitative relationships in the human body also.

Quantitative Metabolism and Requirement in Man

Of the vitamin C which the body receives, a part disappears in the tissues and is evidently consumed in per-

forming its nutritional function; a part leaves the body unchanged, chiefly in the urine; and a part is held by the tissues and fluids of the body.

Extensive studies indicate that normal human blood contains on the average between 1.0 and 1.5 milligrams of vitamin C per 100 grams; and the solid tissues that are characterized by high metabolic activity normally have higher concentrations of this vitamin.

It is especially noteworthy that the amount of vitamin C contained in the body, the rate at which it is destroyed, and the rate at which it escapes through the kidneys, are all subject to relatively large variation even under such conditions as are frequently encountered in daily life (Fig. 25). We cannot doubt that these differences in "level of vitamin C nutrition" are significant in relation to health and efficiency, and that the problem of human requirement for vitamin C should be considered not simply in terms of prevention of scurvy, but rather as a problem of ensuring the maintenance of such concentrations of vitamin C in the blood and body tissues as are conducive to the highest attainable health under all the vicissitudes likely to be met in the course of our lives.

Other things being equal, however, the lower the intake of vitamin C the smaller the amount which appears in the urine; and simultaneously with low intake and low output, low concentrations of vitamin C in blood have repeatedly been found and are doubtless regularly to be expected (Fig. 25). Such quantitative studies as have yet been made with spinal fluid indicate that its level of vitamin C content tends to rise and fall with the level in the blood; and it is reasonable to suppose that this is also true of the body tissues generally, though some of them may fluctuate in lesser degree than others.

An intake of 25 to 30 milligrams of ascorbic acid per normal adult per day, or 1 milligram per 100 Calories of food in family dietaries, appears to be sufficient to prevent scurvy or any other manifest sympton of vitamin C defi-

ciency; and may therefore be taken as a standard of *minimal* adequacy.

But many common infections, injuries, and strains or stresses now seem rather clearly to increase the rate of destruction of vitamin C in the body, and thus to raise the nutritional requirement for it. Most students of the subject have therefore come to feel that a *satisfactory standard* must be higher than the minimum arrived at as indicated in the

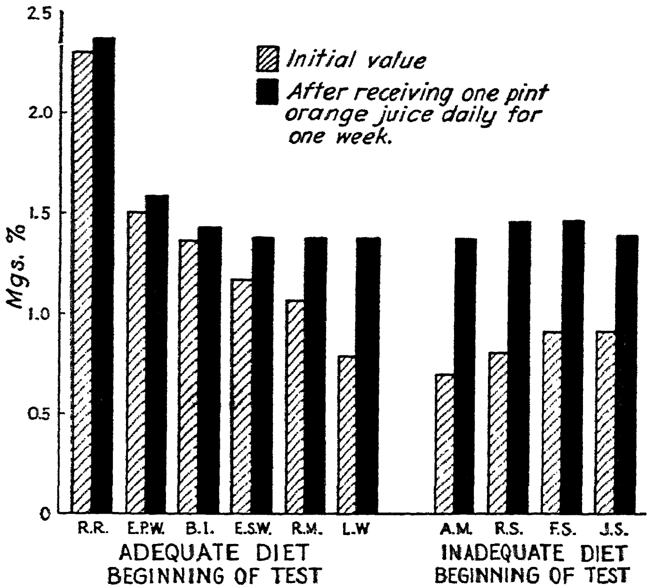

FIG. 25. Vitamin C content of the blood as influenced by diet. The six individuals to the left had all been receiving an apparently adequate diet prior to the beginning of the test. Note, however, the considerable individual differences among them with regard to the initial concentration of vitamin C in the blood (cross-hatched bar), one showing a value distinctly higher, another a value lower than the "usual normal range." The four individuals to the right who were known to have had an inadequate intake of vitamin C prior to the test all showed "subnormal" levels of vitamin C in the blood. After generous amounts of vitamin C in the form of orange juice had been given for a week to both groups, the blood level of vitamin C (solid bar) was found to be about 1.5 mg. per 100 cc. in all cases except the one individual who showed exceptionally high value throughout. Note that values already normal were slightly increased by the liberal intake. (From Farmer and Abt in *The Vitamins* by permission of the American Medical Association, publishers, and by courtesy of the Milbank Memorial Fund.)

preceding paragraph; and have sought an objective basis for the more liberal standard in the determination of the amount which must be taken into the body in order to keep it in a condition of vitamin C "saturation." Different interpretations have been given to this term, or to the concept it represents, which is, of course, quite other than that of a saturated solution in the ordinary physical sense.

The body is spoken of as being "in a condition of vitamin C saturation" when an increase in the level of intake, or a large extra dose, can raise but little the level of vitamin C concentration in the body (as represented in the blood), while a large part of the extra intake does appear promptly in the urine. *A dietary standard aiming to provide for the maintenance of this condition* calls for 60 to 100 milligrams of vitamin C per adult person per day, or from 1.0 to 1.5 milligrams per kilogram of body weight.

Here, as elsewhere, the artificial concentrates should be considered as drugs to be used only when prescribed by a physician; while the non-medical student of nutrition who desires to increase his intake of some dietary factor should do so by shifting the proportions in which he consumes everyday foods. One who desires 100 milligrams of vitamin C may advantageously take it in the form of seven ounces of average orange juice; or may readily figure an equivalent in the form of some other food or foods from the data of Table 12 below or of Table 27 in the Appendix.

As physicians have given six grams of vitamin C in a single dose without unfavorable effects, there is no danger that any selection of foods one might make would involve any risk of injury from surplus of this vitamin.

Expression of Vitamin C Values

In this book we shall follow the growing practice of expressing vitamin C values directly in terms of the substance itself. Above we have expressed nutritional needs in terms of milligrams per day; and below will be found data for

vitamin C (ascorbic acid) contents of foods in milligrams per 100 grams of food.

Data still met in terms of International Units are readily translated into milligrams, for by current definition, 20 International Units = 1 milligram of vitamin C.

Conservation of Vitamin C in the Preparation and Preservation of Foods

From the earliest scientific conception of scurvy as due to the lack of an antiscorbutic substance, it was recognized that in general fresh foods have more and preserved foods have less of this factor. As the concept became clearer, the statement came to take the form that not only are some foods, such as citrus fruits, relatively rich in this factor while others such as bread, butter, meat, and sugar are poor or lacking in it; but also that it is an unstable factor so that cooking and preservation are apt to diminish whatever antiscorbutic value the food originally possesses.

Now that all of the more familiar vitamins are known as distinct chemical individuals *not* closely related in their chemical and physical properties, we see that it is unscientific to try to make broad and simple generalizations or comparisons, for the behaviors of the vitamins will arrange them in different sequences according to the particular chemical or physical condition whose influence is being considered. Yet for most practical purposes we may still regard vitamin C as the most easily destroyed of the known vitamins.

Because many familiar fruits and vegetables such as apples, cabbage, and potatoes may lose a considerable proportion of their vitamin C value in ordinary cooking, it has become customary to emphasize raw food in this connection, and to regard this vitamin as thermolabile,—liable to be destroyed upon heating. Strictly speaking, it is not so much destroyed by heat *per se* as by a process of oxidation which is accelerated by increase of temperature. The rate of destruction is lower when air is excluded by steam or by vacuum; and it is higher when acidity has been reduced or alka-

linity increased by the addition of soda to the food. The destruction of vitamin C is also catalyzed by the presence of even very small amounts of copper. In addition to all these environmental influences (and perhaps others, as yet less clearly defined) there are properties within the natural foods themselves which affect the conservation or deterioration of their vitamin C values. In general the more acid foods hold their vitamin C value better; but if cabbage juice is brought to the same acidity as tomato juice it still will lose more of its vitamin C on heating, because of the natural, inherently higher, oxidation potential of the juice of the cabbage.

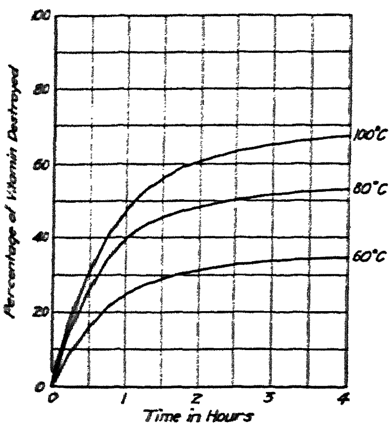

FIG. 26. Curves representing the rates of destruction, at different temperatures, of the vitamin C of tomato juice at its natural acidity.

The destruction of vitamin C upon heating in solution, as in the juices of typical foods, is a process which proceeds at a rate which can be measured experimentally and which has been studied quantitatively with reference to the influence of temperature, time of heating, the acidity or alkalinity of the solution, and other factors.

In the case of tomato juice of natural acidity it was found that boiling for one hour destroyed practically 50 per cent, and boiling for 4 hours destroyed practically 68 per cent of the antiscorbutic vitamin. At lower temperatures there was less destruction in a given time. Figure 26 shows the time curves of the heat destruction of the vitamin at 60°, 80°, and 100° C. It will be noted that, throughout the entire range of times and temperatures covered by these experiments, the destruction was always greater the higher the temperature whatever the time of heating selected for the comparison; and also that at whatever temperature the material was

heated the destruction of the vitamin also continued to become greater the longer the heating was continued.

Thus both time and temperature are important factors in the heat destruction of vitamin C and neither the time nor the temperature can be treated with indifference in any heating operation in which it is desired to conserve as much as possible of the antiscorbutic property of the food. Both time and temperature of heating must be held to the lowest practicable minimum if vitamin C is to be conserved to the best advantage.

The best conservation of the antiscorbutic value of the food also demands that one avoid adding any soda or other alkali to the food, or the water used in its cooking.

Not only is vitamin C more readily destroyed in an alkaline than in an acid solution; any decrease of acidity, even though the material may still remain acid, means that a greater percentage of the vitamin will be destroyed under the same conditions of time and temperature. Thus tomato juice, which lost 50 per cent of its vitamin C in one hour at 100° C. at natural acidity, lost 58 per cent under the same heat treatment when it had been about half neutralized, and 61 to 65 per cent when it had been made very faintly alkaline.

Alkalinity, even in slight degree, appears to be distinctly deleterious to vitamin C even at ice-box temperature, for when the solution last mentioned was stored in an icebox for from one to five days it was found to have lost much the largest part of the vitamin C which had survived the hour of heating. In this case, however, the material was not protected from contact with air during storage.

It is quite clear that one should not speak of the vitamin as being "destroyed at" a certain temperature; but rather as being *more rapidly* destroyed the higher the temperature. The question is not so much *whether*, but rather *in what degree* (or at what rate), the vitamin is destroyed "at boiling," "at steam-table temperature," etc. If, for instance, the material shown in Fig. 26, after losing 20 per cent of its

vitamin C at 100° C. (boiling temperature) was thereafter kept hot for serving by placing it on a steam-table at 60° C. the destruction would continue, only at a lower rate.

The American Medical Association's Council on Foods issued in July 1939 a report on "Allowable claims for the vitamin and mineral content of canned fruits and vegetables intended for infant feeding" which includes a Decision that sufficient experimental evidence has accumulated to warrant the view that vitamins A and G (riboflavin) are little affected by good modern canning procedures, but that vitamins B_1 and C are more or less adversely affected, "the degree of destruction depending on the characteristics of the food itself, the time and temperature of processing, and possibly other factors." In the future, therefore, they propose to recognize claims for vitamin B_1 and vitamin C values of such canned foods only when "supported by acceptable evidence of the potency of the finished product."*

One should, therefore, not attempt to answer broad, undiscriminating questions as to whether or to what extent a given vitamin is destroyed by a given cooking or canning process; for the rate of such destruction differs too widely among different foods, and is also influenced by too many environmental conditions.

It may safely be said, however, that *among* the conditions which are favorable to conservation of vitamin C are: to minimize time of exposure, temperature, and contact with air (or even with dissolved oxygen), and to add no soda.

As vitamin C is readily soluble in water, the rejection of cooking water, or of the fluid contents of the can, may involve a loss no less serious than that of the actual destruction which takes place in the cooking and canning processes. In some careful experiments the loss in cooking has been found to have been even much more largely due to the dissolving away of the vitamin than to its actual destruction.

**J. Am. Med. Assoc.* 113, 215 (July 15, 1939).

Thus, Wellington and Tressler* found that in the boiling of shredded cabbage less than one-sixth of the original vitamin C was destroyed, while about two-thirds of it was lost from the vegetable in the sense that it passed into the cooking water. When larger pieces of cabbage were boiled, the amount extracted was less. The utilization of "pot liquors" in making soups and stews has doubtless helped to protect many poor families from scurvy.

It is recorded that in a prison camp in Siberia the ration for a long time consisted of bread, preserved fish, and an occasional very nondescript vegetable soup. The more fastidious prisoners who considered the soup unfit for them to eat nearly all developed scurvy, while the humbler ones who took the soup escaped the scurvy.

Quantitative Distribution of Vitamin C in Foods

There is much of both scientific interest and practical value in a consideration of the different types of food as sources of vitamin C now that we are beginning to appreciate the great importance of this constituent of our food to our nutritional wellbeing and resultant health and efficiency.

In a fairly recent study by Stiebeling** of presumably typical American dietaries it was found that citrus fruits and tomatoes, while representing less than five per cent of the expenditure for food and furnishing less than two per cent of the total protein, furnished over 37 per cent of the total vitamin C. Potatoes and sweetpotatoes are not nearly so rich, but their large place in the food supply makes them important sources contributing about 23 per cent of the total vitamin C. Green and yellow vegetables show a contribution of nearly 13; all other fruits and vegetables about 20; milk and its products 5 to 6; meats and fish, breadstuffs and cereals,

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*Wellington, M. and D. K. Tressler 1938 Influence of method of cooking on vitamin C content of cabbage. *Food Research* 3, 311–316.

**Stiebeling, H. K. 1936 Report Serial No. R 409, Bureau of Labor Statistics, U. S. Department of Labor.

together less than 2 per cent of the vitamin C; and sweets, fats, and eggs only negligible amounts, if any.

Assuming, as we doubtless may, that the data thus studied by Stiebeling are fairly representative it will be seen that we derive probably nine-tenths of our vitamin C from fruits and vegetables, and most of the remainder from milk. Doubtless the flesh foods could be made to furnish a larger proportion if we ate them, as the Eskimos do, in larger amounts, with less intervention of storage and cooking between slaughter and consumption, and with a reversal of our usual practice of taking the muscle meats for ourselves and giving the glandular organs to the dogs. Another and perhaps more important consideration in clearing up what some regard as an inconsistency between our view of vitamin C and some of the reports upon food habits of carnivorous peoples is that the latter have sources of vitamin C which are apt to escape the attention of explorers and even anthropologists. The natives of Kamchatka were anthropologically described as living exclusively on meats and fish; but a later more meticulous investigation revealed the fact that they also eat berries, bark, and leaves. Evidently so did those Canadian Indians who were supposed to be carnivorous until occasion arose for them to teach Cartier's men the importance of evergreen twigs and leaves as antiscorbutic food.

There probably are no strictly carnivorous peoples; for it is much more probable that explorers who think they have found such have failed to observe or to appreciate the significance of the eating of berries and the chewing of bark, roots, and twigs. Of course it may also be true that people descended from untold generations of Arctic ancestors may have intensified, as a characteristic of survival value under their conditions, the property of being able to get along with less vitamin C than we require.

To return to the consideration of the different types of foods as sources of the vitamin C of our normal dietaries, it is noteworthy that the breadstuffs and cereals which furnish such a large proportion of our food-calories and

protein are such insignificant sources of vitamin C in the forms in which we ordinarily eat them. These seeds, however, and also the mature legumes, form vitamin C when they germinate, so that, in lack of other adequate sources, cereal or legume seeds may be germinated and eaten with their young sprouts. Evidently there is here some process of change which the sprouting seed performs efficiently; and which our bodies perform very inefficiently if at all. In the plant cycle too, it would seem to be in some sense a reversible process; the young green pea is a good antiscorbutic, loses this property as it matures, but regenerates it when sprouting. The oxidation-reduction or "respiratory" behavior of vitamin C *in vitro* here finds a clearcut relation to metabolism in the plant, while in animal metabolism its behavior in this direction is as yet somewhat overshadowed by the importance of its function in the making and maintenance of intercellular substance, as mentioned earlier in this chapter.

Among edible seed pods, *string beans* and *green peppers* have been found to be rich sources.

Leaves, such as *cabbage*, *lettuce*, and *spinach*, are also rich in vitamin C: they may be counted as excellent sources when eaten raw, and even though they lose a considerable proportion of their vitamin C in ordinary cooking, they are still fairly good sources when cooked. In *celery*, the leaves have been found to be even richer in vitamin C than are the succulent stalks. *Turnip greens* and *watercress* are among the other edible leaves which have been demonstrated to be good sources of vitamin C.

Onion, an edible bulb, has also been found to be a good source of vitamin C.

Asparagus, a succulent growing tip, is highly potent when raw, but loses much in ordinary cooking.

Among roots and tubers, *carrots*, *turnips*, and *potatoes* may be mentioned here. *Carrots* received considerable attention from Hess and his coworkers who emphasized the difference between old and fresh young carrots particularly after cooking. They found that 35 grams of old carrots

sufficed to protect a guineapig from scurvy when fed raw but not after cooking, while in a parallel test with fresh young carrots 25 grams proved adequate for complete protection even after cooking. They pointed out that in such cases as this the fresh young vegetable may have a double advantage over the older and tougher, since in the first place the younger or fresher specimens may be richer in antiscorbutic vitamin to start with; and also, as the older, tougher vegetables require more prolonged cooking, they are apt to undergo a greater loss of vitamin C during the cooking process.

Largely as the result of this experience with carrots, Hess has emphasized the view that vegetables must be expected to vary considerably in their content of vitamin C according to their freshness and age. While young carrots were much superior to old carrots in antiscorbutic value, he found that slightly green tomatoes contained less vitamin C than did those which were fully ripe. So far as fruits and vegetables are concerned, our present limited knowledge suggests that the degree of maturity at which each fresh fruit or vegetable is most prized is probably not far from that at which it has greatest vitamin C value.

Potatoes, while containing vitamin C in distinctly lower concentration than do some other common foods, are yet of great importance as antiscorbutics because of the quantities in which they are consumed. Weight for weight cooked potatoes are comparable as antiscorbutics with (raw) apples, and in most families the potato is consumed in much the larger quantity. Different investigators have reported a number of experiments with potatoes cooked in different ways and with variable results which suggest a number of possible factors involved in the destruction of vitamin C in this case.

Turnips have high vitamin C value when eaten raw. They and their juices served as important antiscorbutics in the countries of Northern Europe which were more or less blockaded during the World War.

Among fruits, the citrus,—especially oranges and grapefruit,—and tomatoes, which are botanically fruit though classified commercially as a vegetable, are the sources of outstanding importance and qualified also for increasing prominence in the dietary on the grounds of economy and general acceptability. Milne, in his essay on fruit, gives first place to the orange, and returns to it for his peroration! Beside its many other virtues, the *orange* is one of the most potent and popular of antiscorbutics.

The *grapefruit* is almost as rich in vitamin C as the orange, and has a fine flavor all its own. Delicious also is a mixture of grapefruit and orange juices.

Tomatoes are somewhat less rich than grapefruit and distinctly less rich than oranges in their vitamin C content; but, like grapefruit and its juice, they hold their vitamin value well when preserved by canning, and the canned product is economical and available almost everywhere at all seasons of the year. Often in recent years, citrus fruits have been about as cheap as canned tomatoes, but at times when oranges have been expensive the juice of canned tomatoes has been largely substituted for orange juice in infant feeding.

Apples are more variable and less potent than citrus fruits as antiscorbutics. Having been so widely cultivated, apples have become differentiated into well-marked varieties, some of which differ from each other as much, in their vitamin C content, as if they were different species. Yet to recognize each variety separately in nutrition work would be prohibitively cumbersome. For present purposes therefore we present in Table 12 an average of the middle group of varieties.

All of the averages in Table 12 are accompanied by their probable errors so that the reader who so desires may readily compute the probable errors of the differences to satisfy scientific curiosity as to whether they are real or accidental. Assistance in making such calculations and interpreting the results may be obtained from Appendix E.

TABLE 12.—VITAMIN C IN THE EDIBLE PORTION OF CERTAIN FOODS
MILLIGRAMS PER 100 GRAMS

Food	No. of Cases	Vitamin C Mean	Vitamin C Probable Error of Mean
Lemon (or juice)	37	56.	±1.1
Orange (or juice)	148	54.	±0.55
Grapefruit (or juice)	109	39.3	±0.44
Cabbage, raw	18	35.0	±1.7
Strawberries	16	34.4	±3.1
Cantaloupe	70	29.2	±0.9
Turnip, fresh raw	17	26.2	±1.8
Tomato (or fresh juice)	300	22.7	±0.41
Peas, fresh young, green, raw	120	22.4	±0.44
Asparagus, raw	38	19.8	±1.4
Radishes	13	15.7	±1.2
Beans, snap or string, raw	111	15.4	±0.39
Lettuce	21	13.5	±2.17
Potatoes, raw	82	12.6	±0.33
Corn, sweet, raw	24	9.4	±0.24
Peaches	26	8.7	±0.56
Bananas	98	7.6	±0.20
Apples (medium varieties)[a]	69	7.0	±0.22
Celery (stalks)	22	6.8	±0.41
Watermelon	100	6.6	±0.15
Plums	22	5.4	±0.46
Pears	18	4.1	±0.43
Carrots, raw	16	4.0	±0.30
Milk	218	2.18	±0.018

[a]Varieties here averaged were: Astrachan, Baldwin, Ben Davis, Esopus, Golden Delicious, Gravenstein, King, Newton Wonder, Northern Spy, Rhode Island, Rome Beauty, Roxbury Russet, Spitzenburg, Stayman, Winesap, Winter Banana, and Yellow Newtown.

EXERCISES

1. Purchase oranges, grapefruit (or canned grapefruit juice), apples (noting the variety, if known), and bananas in your local market, recording the cost of each purchase and determining the weight of its edible portion. How do these fruits compare in pecuniary economy as sources of vitamin C?

2. Compare apples, bananas, oranges, and grapefruit (or its juice) as to the amount of vitamin C furnished (1) in each 100-Calorie portion; (2) per gram (or per 100 grams) of protein.

Arrange these fruits (and perhaps others) in the order of their merit as means of increasing the vitamin C value of a dietary with the least change in its total calories, or total protein, or both.

3. Prepare a critical compilation and discussion of all information afforded by the library facilities available to you, on the extent of the losses of vitamin C involved in different recognized methods of cooking and serving potatoes. Taking account of all losses, what percentage of the vitamin C content of a raw potato probably actually enters the nutrition of the consumer? Could this be materially improved without undue change of household customs? If so, how?

4. "Look up the literature" of 1940 and later* on the newer knowledge of the phenomenon known as *saturation* of the body with vitamin C, and the significance of the maintenance of "saturation" for health.

5. Similarly has there been, since the present text was written in 1940, any clarification of the idea that steady liberal intakes of vitamin C may in some way bear upon "the preservation of the characteristics of youth" (McCollum and Simmonds' phrase), *i.e.*, the postponement and amelioration of the aging process?

6. Does this recent literature develop a clear relation between the nutritional significance of vitamin C and that of the calcium metabolism, or of the acid-base balance?

7. In Great Britain during the World War, when importation of fruits and vegetables was abnormally difficult, the juice of home-grown turnips (including the socalled "swedes") acquired a considerable vogue as antiscorbutic. From the data of Table 12, examined in the light of the explanations in Appendix E, do you feel confident that turnips are significantly richer in vitamin C than tomatoes which (fresh or canned) are usually more regularly available and of uniform quality, and whose juices are more easily prepared?

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Chapter XII

THIAMIN (VITAMIN B OR B_1)

Discovery and Identification of the Substance temporarily called Vitamin B and now named Thiamin

The existence of the substance now named *thiamin* was discovered both through studies of the disease beriberi and through experiments in normal nutrition. Here, as often, discovery was a process of gradual accumulation of evidence until finally it became convincing.

Beriberi manifests itself primarily as a nerve disease and usually appears first as a weakness and loss of neuromuscular coordination in the feet and legs, equally on both sides. In formal terminology it is *a multiple peripheral neuritis*.

In 1878-1883, when the entire enlisted force of the Japanese navy was about 5000 men, each year's sick-lists showed from 1000 to 2000 cases of beriberi among them. Takaki, as a patriotic son of Japan and medical officer in her navy, could not reconcile himself to this enormous annual morbidity of 20 to 40 per cent from one disease. Careful study convinced him that it was not due to tropical climate, for British crews in tropical waters were not thus affected; nor to lack of care in sanitation, in which he found the Japanese as scrupulous as other sailors. He then obtained authority for a large-scale experiment with the ration. Two ships each carrying about 300 men were sent in succession over the same long cruise but with different rations. On the first ship, which was furnished with the then standard

Japanese ration containing a greatly predominant amount of white rice, more than two-thirds of the men suffered from beriberi; while on the second ship, with a ration in which part of the white rice was replaced by barley, vegetables, fish, meat, and canned milk, only a few men developed beriberi, and these were found not to have eaten their share of the new foods. So convincing was the evidence, and so striking the contrast, that within a very short time thereafter Takaki was able to obtain a similar change of ration throughout the Japanese navy and this change was followed by a prompt decrease in beriberi cases from a very high percentage to a mere fraction of one per cent.

The reported figures were as shown in Table 13.

TABLE 13.—BERIBERI IN THE JAPANESE NAVY

YEAR	TOTAL FORCE	CASES OF BERIBERI	PERCENTAGE
1880 Old ration.............	4,956	1,725	34.81
1881 " "	4,641	1,165	25.06
1882 " "	4,769	1,929	40.45
1883 " "	5,346	1,236	23.12
1884 Ration changed.........	5,638	718	12.74
1885 New ration.............	6,918	41	0.59
1886 " "	8,475	3	0.04
1887 " "	9,106	0	0.00
1888 " "	9,184	0	0.00
1889 " "	8,954	3	0.03

Takaki received prompt and generous official recognition for this really great achievement in practically ridding his country's navy of this disease which had previously been so prevalent: he was promoted, made a baron, and appointed the permanent head of a Government hospital and training-school in Tokyo. Yet there was a long lag not only in popular but even in scientific and professional understanding of what he had accomplished.

Why was it so many years before the people of the Orient generally began to share the benefit from what had been

demonstrated so clearly and acted upon so promptly in the Japanese navy? Takaki had really rid the navy of beriberi by changing the ration, and he had been explicit in saying so. He had even emphasized the fact that the fault in the older ration was nutritional. He had stated the facts as he saw them clearly and emphatically enough; but with world medical opinion, and so with the people generally, his statements remained ineffective because his explanation was inadequate. He attributed the superiority of the reformed ration simply to its higher protein content, which others rightly regarded as unconvincing. It was a time of great activity in the sanitary applications of the then new and brilliantly developing science of bacteriology; and naturally some advances in sanitation had been made in the same period in which Takaki had secured the reform of the ration. So with no adequate nutritional explanation at hand, it seemed to most medical men more probable that the diminished frequency of the disease in the Japanese navy was due to some sanitary cause, even though no infective agent had been discovered. Hence Takaki's work was largely forgotten, and most of those who had to deal with beriberi regarded it as probably due to some undiscovered infective agent.

Such was the view of the American Army Medical Officers when they took over the Philippines during and after the war with Spain. Their striking experience with beriberi in the Bilibid prison at Manila was, however, very influential in reviving the nutritional hypothesis of the disease.

When officers of the United States army took charge of this prison, they found what at first appeared to them as an abuse in the fact that the poor prisoners accustomed to live so largely upon rice had been fed with rice of low commercial quality, uneven in size and dark in color. This they promptly replaced by "high grade" rice, consisting of uniform, plump, well-polished, white kernels. Notwithstanding their attempts at better and more humane treatment of their prisoners, however, these officers were soon distressed by an epidemic of beriberi in their prison population.

The monthly record ran as shown in Table 14.

During the first several months of the epidemic every effort at further sanitary improvement was made, the responsible medical officers thinking only in terms of the theory that beriberi was due to infection. Failure of their earnest sanitary efforts led them to further study of the literature of beriberi, and in the light of the papers which Takaki had published several years before and which had been generally forgotten meanwhile, they finally began to think that the nutrition hypothesis might be worthy of trial. Accordingly, a change of ration was then made; and it was followed by practical disappearance of the disease in the course of about three months (Table 14).

TABLE 14.—BERIBERI IN THE BILIBID PRISON IN MANILA

YEAR	MONTH	CASES	DEATHS
1901	November	2	0
Ration changed			
1901	December	52	2
1902	January	169	12
1902	February	1087	16
1902	March	576	15
1902	April	327	15
1902	May	310	19
1902	June	451	17
1902	July	233	33
1902	August	571	24
1902	September	522	31
Ration again changed October 20th			
1902	October	579	34
1902	November	476	8
1902	December	89	3
1903	January 1-15	4	0

It was at about the same time with this experience in the Bilibid prison that a nutritional interpretation was given to the observations first published by Eijkman, a Dutch physician working in the East Indies, upon "an illness of fowls similar to beriberi." He noticed that such a disease developed

in fowls which lived in the bare yard of a prison hospital and subsisted almost entirely upon left-over rice from the prisoners' tables; and by systematic trials he found that by confining fowls strictly to a polished-rice diet he could induce experimental beriberi with great regularity. Eijkman, however, did not at first explain the experimental disease in direct nutritional terms but rather upon the hypothesis of the presence of some unknown injurious substance; so that, as English writers afterward expressed it, "the pharmacological bias" at first prevented the nutritional significance from being seen. It was in papers published after the turn of the century and dealing with the work of Grijns as well as of Eijkman, that the experimentally induced disease was first clearly stated to be a *nutritional* polyneuritis.

Then followed about a quarter-century of very active search for the *antineuritic substance*. Several groups of investigators in different countries contributed toward the working out of methods for the separation of this substance and the study of its chemical nature. Funk in a paper published near the middle of this period proposed the name *vitamine*. Thus in this case the name was coined and proposed several years after the discovery of the existence and of some of the most important properties of the substance; and several years before its complete chemical identification.

It is to R. R. Williams that we feel most deeply indebted for knowledge as to the chemical nature of this substance, and preference is given to the name *thiamin* (or *thiamine* or *thiamine chloride* or *hydrochloride*) which he proposed for it after its chemical identification had been completed. The structural formula may be found on page 389 of Sherman's *Chemistry of Food and Nutrition*, Fifth Edition. The complete chemical name is obviously too long for everyday use. The name *thiamin* (*e*) tells about as much of the chemical nature of the substance as can be conveyed in one short word. Because it is considered preferable that the name of each chemical individual shall suggest its chemical nature and shall not imply a therapeutic claim, we prefer *thiamin* to *aneurin* as

the permanent name for the substance temporarily called vitamin B or B_1.

The American Institute of Nutrition, the American Society of Biological Chemists, and the American Medical Association's Councils on Foods and on Pharmacy and Chemistry are among those who have formally adopted and recommended the use of the name thiamin. At present (1940) the terms thiamin, aneurin, and vitamin B_1 are used interchangeably for the antineuritic substance once called antiberiberi vitamine or vitamin B.

In 1911 Osborne and Mendel published the reports of their epoch-marking *Feeding Experiments with Isolated Food Substances* (Carnegie Institution of Washington, Publication No. 156, Parts I and II, 1911) and began their series of articles in *The Journal of Biological Chemistry*, Vol. 12 *et seq*. And in 1912 appeared the full account of the work by Hopkins which we noted in Chapter I.

While their work had originally been planned as a study of the nutritive values of individual proteins, Osborne and Mendel quickly perceived that purified protein and carbohydrate with butterfat and a good salt mixture lacked some nutritional essential which the water-soluble part of milk contained. This they supplied first by including in their experimental food mixtures generous proportions of what they called "protein-free milk," made by removing the coagulable proteins from whey and drying the clear filtrate. Soon they found that this nutritional need could be met also by the feeding of yeast, the material from which Funk was extracting what he called yeast vitamine. Then soon after this McCollum became convinced by his own experiments and those of Osborne and Mendel, that this water-soluble growth-essential was the same substance which prevented and cured beriberi. As he had already found that a fat-soluble factor was essential, he now proposed the terms *fat-soluble A* and *water-soluble B*. But the catchy term "vitamin" had stuck, and in 1920 Drummond proposed (as noted in Chapter XI) that the fat-soluble substance be called vitamin

A: the water-soluble antineuritic substance, vitamin B; and the antiscorbutic substance, vitamin C.

In laboratory feeding experiments it came to be customary to use yeast as a source of vitamin B, and to attribute to vitamin B whatever of "vitaminic" values yeast was found to have.

To this extent, then, the term vitamin B covered also the other water-soluble vitamins contained in yeast and confused them with the antineuritic substance. Inasmuch, therefore, as the early literature of vitamin B belongs in part also to the other yeast vitamins, all these are sometimes collectively called the "B vitamins" or the "vitamin-B complex" or "B group of vitamins."

Later, to distinguish it from the other members of the "B group" which were by then recognized to exist, the antineuritic substance (our present thiamin, but not structurally identified at that time) was designated vitamin B_1.

Nutritional Functions of Thiamin

This antineuritic substance (the original vitamin B, now vitamin B_1, or thiamin) has at least three other more or less specific nutritional functions: it is essential to growth, it has an important part in the maintenance of appetite, and it is concerned in at least one stage of carbohydrate metabolism.

An illustration of its relation to growth may be seen in Fig. 27. Seven rats of a litter were fed, one at a thiamin level but little above that required to prevent deficiency disease, and two each at three successively higher levels. Although all were healthy, the rate of growth was quite definitely determined by the thiamin intake.

The effects upon growth and upon appetite may well be inter-connected; and to the favorite conundrum of Osborne and Mendel, "Does he eat more because he grows faster, or grow faster because he eats more?" the best answer is probably, "Both."

The relation to appetite is, however, specific in two

senses: (1) While appetite may decline as the result of any of several vitamin deficiencies, no other known vitamin has such a prompt and apparently direct effect upon appetite as has thiamin. (2) The relation to appetite is also specific in the sense that it is a true effect upon appetite as a physiological condition and function of the body, and not merely a matter of making the food appetizing; for when the vitamin is given separately the experimental animal will

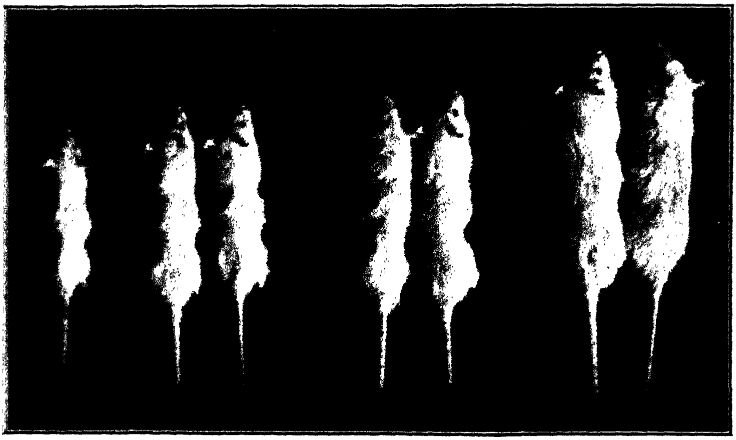

FIG. 27. Growth of healthy individuals as influenced by the level of thiamin, the food being allowed *ad libitum*. (See text.)

return with appetite, and often with dramatic promptness, to the same food which it has previously refused.

To what extent the weakening of the organism in thiamin deficiency is due to starvation from lack of interest in food is still a research problem; and to what extent and in what circumstances it is feasible and desirable to stimulate the appetites of patients by administration of thiamin concentrates is a problem for the physician. In good scientific literature one may meet the simple statement that this vitamin increases or stimulates the appetite; but at present (1940) there is a tendency to qualify this so sharply as to limit it to a statement that this vitamin restores an appetite which has declined for lack of it.

In our opinion, administrations of the vitamin in concentrated form and as therapeutic treatment should always be under medical advice.

Without any encroachment upon the province of the physician, we may emphasize the importance of cultivating such dietary habits as ensure, along with ample provision for other nutritional factors, a good intake of thiamin in the normal daily food. With children this is a prominent factor in good growth, partly through the stabilization of the appetite. With adults, while growth is no longer concerned, there is still value in the toning-up and stabilizing of the appetite, of the digestive mechanism, and of the processes involved in the carbohydrate metabolism.

Peters and his coworkers at Oxford have especially studied the relation of this vitamin to the process of metabolism. They found an abnormal accumulation of lactic acid and of the closely related pyruvic acid in the brain tissue of pigeons which had been kept on thiamin-deficient food; and also that sections of such brain tissue did not show the same power as parallel sections from a normal brain, to oxidize glucose in a suitable respiration apparatus. Furthermore it was shown that, when thiamin was injected into polyneuritic pigeons, the brain tissue was restored to normal power of burning glucose completely to carbon dioxide.

Williams and Spies emphasize the view that similar or analogous relationships exist in all the various tissues in which carbohydrate metabolism occurs; thus explaining the helpfulness of liberal thiamin intake in widely varied physiological and clinical conditions.

The work of Osborne and Mendel and that of Brodie and MacLeod showed that the thiamin content of body tissues may be influenced by that of the food.

More recently Harris, Leong, and Ungley* report that, as in the case of vitamin C so also with thiamin, the amount excreted in the urine reflects to some extent the level of in-

*Harris, L. J., P. C. Leong, and C. C. Ungley, *Lancet* 1938, I, 539; Ungley, C. C., *Lancet* 1938, I, 981; Harris, *Vitamins and Vitamin Deficiencies*, Vol. I.

take and concentration of the substance in the tissues and fluids of the body; and that the thiamin content of the blood is lowered in conditions which involve either a diminished nutritional intake or an increased rate of destruction. The increased demand of pregnancy may also have the effect of lowering the level of thiamin concentration in the blood.

Harris and other English workers have given special attention to the relation of thiamin intake to the heart action. Experimenting with rats they found that shortage of thiamin in the food, with resulting incompleteness of carbohydrate metabolism and increase of pyruvic acid in the blood, slows the action of the muscles of the heart, often from the rat's normal rate of about 500 beats per minute to 350 or less. This *experimental bradycardia* is quickly curable by injection of thiamin or by ingestion of food which contains it. Such experiments have even been made a method of estimating the thiamin (vitamin B) values of foods.

Measures of Thiamin

The technique of measurement of the thiamin contents of foods and of artificial concentrates is subject to rather rapid change at present and need not detain us in our present study; for now that thiamin is readily available in pure form all methods for its determination in foods or other materials are of course standardized by control measurements with pure thiamin. And for the same reason we can now express the amount of thiamin contained in a food or desired in a diet in direct terms, just as we have done in the cases of protein, phosphorus, calcium, iron, and ascorbic acid; though the absolute amounts of thiamin concerned in our normal nutrition are so small as to make it more convenient to use a unit of weight even smaller than the milligram.

The growing custom is the one recommended by Williams and Spies, namely, the expression of amounts such as are concerned in daily food intakes *in terms of micrograms*. The microgram is the millionth of a gram, or the thousandth of a

milligram. It is often represented by the Greek letter gamma (γ).

By official definition of the Health Organization of the League of Nations in 1938 the International Unit of thiamin or vitamin B_1 is 3 micrograms of actual thiamin (thiamine chloride). The United States Pharmacopeia (U.S.P.) Unit is by official definition the same as the International Unit.

Human Requirements and Dietary Standards

Cowgill proposed about 10 micrograms of thiamin per kilogram of body weight as a daily allowance for normal adults.

M. S. Rose recommends at least 15 micrograms of thiamin per 100 Calories in family dietaries or general food supplies; and cites with apparent approval* the League of Nations recommendation of twice this amount.

Williams and Spies, from a critical study of all available evidence in the light of further laboratory work on the chemical rôle of thiamin in the intermediary metabolism of the organic foodstuffs, conclude that the thiamin need is proportional to the non-fat calories rather than the total calories of the food supply or energy metabolism. They interpret the evidence as indicating that *for every* 100 *non-fat Calories* supplied in the food or metabolized in the body there is need of 27 *micrograms of thiamin.*

Both scientifically and practically, it is important to grasp firmly and keep clearly in mind the fact that all the foregoing estimates of thiamin requirement are based largely on *data of a different kind* from those used in arriving at the protein, phosphorus, and calcium requirements discussed in earlier chapters.

The "base line" in the study of protein, phosphorus, or calcium need is the *average* need of *all* the *individual* cases of which adequate records were to be found; whereas the corresponding base line in the study of thiamin requirement is not the average need of all the individuals but the *need of*

*Rose's *Feeding the Family*, Fourth Edition (1940), p. 127.

those in each group *who needed most.* For a dietary on which "beriberi occurred," no matter in how small a proportion of the group which received the dietary, is put down as containing not enough thiamin. In a very large proportion of cases the dietaries thus reported as deficient were demonstrably deficient only for the minority whose needs were highest. Thus the whole argument and computation start from a much more liberal (quantitatively higher) base line or initial concept in estimating the thiamin (vitamin B) requirement than in estimating, for instance, the calcium or phosphorus requirement.

And, strange to say, with all the widespread enthusiasm for liberal intakes of thiamin that now exists, there seem to have been as yet (1940) no comprehensive full-life and successive-generation experiments with different liberal level of nutritional intake of this factor, such as have already been discussed in our study of calcium in Chapter VIII and will be mentioned in connection with riboflavin and vitamin A in subsequent chapters.

Thiamin Contents of Typical Foods

Thiamin is of very widespread occurrence in the animal and vegetable kingdoms, and therefore in foods of both animal and plant origin unless these have been artificially refined or otherwise subjected to loss. Table 15 herewith and Table 27 in the Appendix give the results of our study of all available data on typical foods, stated in each case in terms of a range which as more fully explained in the footnote to Table 27 is intended as a reasonable estimate of the bounds within which the true average probably will be found.

Muscle meats appear from recent work to be richer in thiamin than previously supposed. Pork muscle seems decidedly richer than beef muscle, though this difference is doubtless somewhat diminished by the more drastic cooking which pork needs as a safeguard against trichinosis.* The few investigations thus far available do not show a corresponding

*See also Chapter XXI.

species difference in the glandular organs and we have therefore averaged the scanty data on the *kidney* and *liver*, respectively, from cattle, sheep, and swine together. These glandular organs show thiamin values intermediate between beef muscle and pork muscle. Again, the quantitative differences may be somewhat modified by cookery.

The thiamin values here given for *milk* and for *eggs* are doubtless more stable. When comparing them with each other and with meats, the fact that milk is much more watery should be kept in mind. When milk is as liberally used as (for several nutritional reasons) is wise, it becomes one of the major sources of thiamin in the dietary.

Cereal grains and their milling and bakery products call for special attention, because while the seed as a whole is relatively rich in thiamin very much the largest part of this is rejected in the milling of refined white flour or rice. The bran and germ (embryo) thus milled away, and the yeast introduced in breadmaking, are all fairly rich in thiamin, but are only minor sources in the amounts in which they enter into the majority of present-day American dietaries. It is (in February 1940) too early to judge whether the thiamin-rich baker's yeast recently described by Frey will materially change this situation. A white flour made to retain the germ without the bran, or with germ returned in the same proportion originally present, is not nearly so rich in thiamin as is whole wheat flour. Only about one-eighth as much thiamin can be expected in white polished rice or in white flour or bread as in the corresponding whole grain products; and, of course, the *commercial sweets and fats* contain only traces of thiamin, if any.

The legume seeds, *beans, lentils, peas, and peanuts* rank near or with the whole-grain cereals as rich sources of thiamin. This is even true of *fresh young green peas*, notwithstanding their higher water content.

The *other vegetables* and *the fruits* show moderate variations either way from an average of about 100 micrograms of thiamin per 100 grams of the edible material in the moist

TABLE 15.—THIAMIN IN TYPICAL FOODS: MICROGRAMS PER 100 GRAMS

Food	Range Within Which Average Will Probably Be Found
Foods of Animal Origin	
Beef muscle	110–210
Chicken (and fowl)	90–380
Lamb (and mutton)	200–300
Pork muscle	700–1400
Kidney (of cattle, sheep, and swine)	400–500
Liver (of cattle, sheep, and swine)	300–420
Milk	40–65
Eggs	140–160
Egg white	trace
Egg yolk	350–440
Grain Products	
Oats (oatmeal)	345–770
Rice, entire	240–300
Rice, white (polished)	30–40
Wheat, entire	500–660
White flour	60–100
White bread	55–85
Whole wheat bread	240–400
Dry Legumes	
Beans, pea or navy, dry	315–510
Beans, Lima, dry	450–600
Peas, dry	300–620
Peanuts	500–600
Other Vegetables and Fruits	
Apples	20–55
Bananas	50–100
Beans, snap or string	55–95
Cabbage	70–140
Carrots	60–140
Lettuce	50–125
Orange (or fresh juice)	75–145
Peas, fresh young green	270–495
Potatoes	95–165
Spinach	95–155
Tomato (or fresh juice)	70–115

state in which most fruits and vegetables are marketed. It is a common mistake,—met even in some otherwise authoritative books, and often in oral discussion,—to treat the succulent fruits and vegetables as if, containing only about one part per million of thiamin, they were therefore nearly negligible sources. But because of their succulent character (and relatively low calories) fresh, including frozen and cold-stored, fruits and vegetables can be consumed in liberal quantities with pleasure and without fear of making the dietary too fattening. Moreover, our newest knowledge of nutrition tells us even more clearly than did the "newer knowledge" of a few years ago, that liberal use of such fruits and vegetables is so advantageous to health and efficiency as to be especially good dietetics and food economics. A normal adult dietary which gives due recognition to present-day knowledge will very probably contain two to three pounds of total fruit-and-vegetables in the course of a day, and when used in such quantities these foods are among the major sources of thiamin in the dietary. A more abundant use of fruits and vegetables, the selection varying with individual preference and with market supply and price, is certainly one of the very best ways of improving the dietary in several of its mineral and vitamin factors.

Stability of Thiamin in the Storage and Preparation of Foods

Mature, dry, unbroken seeds seem to contain their thiamin in a relatively stable form and favorable environment. In one published report, the evidence of local records was accepted as showing that wheat taken from the bottom of a certain tight dry granary compartment was a century old. On feeding to experimental animals it was found to be a potent source of thiamin. Obviously there was no means of knowing just how much thiamin it had originally contained; but obviously also the thiamin of this wheat had shown good stability.

Like other thermolabile substances thiamin is more stable to heating in a dry state than in solution.

Thiamin, like vitamin C, is (other conditions being equal) distinctly more stable in a moderately acid than in a correspondingly alkaline solution.

In tomato juice, for instance, the experiments of Gross showed the rate at which the destruction of thiamin occurred was gradually increased with rising temperature (thus correcting the early impression that the substance was "stable at 100° but destroyed at 130°"), while Burton's work brought out clearly the destructive effect of additions of alkali on whichever side of the neutral point.

In the former investigation, heating was always at the natural acidity of the tomato juice (pH = 4.3). At 100° C., this heating destroyed 20 per cent of the original thiamin in 4 hours; at 110°, 33 per cent; at 120°, 47 per cent; and at 130°, 55 per cent. Clearly there is here no sudden destruction, or even sudden rise in the rate of destruction, at any definite temperature. The chemical reaction which changes the thiamin into something else is increased in its rate as the temperature rises, but no more so than most chemical reactions.

Burton also found a destruction of 20 per cent of the thiamin of tomato juice when heated 4 hours at its natural acidity; when the acidity was about half neutralized before the heating, the destruction rose to 31 per cent; and when it had been brought barely over the neutral point (pH = 7.9) the destruction for the same time and temperature of heating was 70 per cent.

While vitamins B_1 and C (thiamin and ascorbic acid) thus show a similarity in their thermolability and susceptibility to alkali, we would not be justified in assuming from these facts similarity of behavior of vitamins in general; for Morgan has found that the impregnation of drying fruit with sulfurous acid diminishes the loss of vitamin C but increases the loss of vitamin B_1 (thiamin).

In a recent study in the Federal Bureau of Home Economics*, about 20 to 25 per cent of the thiamin of spinach, potatoes, and snap beans was destroyed when these vegetables were cooked by boiling, while smaller additional amounts were dissolved away. Soda, added to preserve the green color of the snap beans, more than doubled the destruction of thiamin in cooking. Cooking carrots in boiling water or under steam pressure, and double-boiler cooking of cereals did not cause any measurable destruction of thiamin; but roasting pork loin destroyed 40 to 45 per cent of the thiamin present. Baking wholewheat bread appeared to lower its thiamin content about 15 per cent.

Why and How to Have a Thiamin-rich Diet

The trend of opinion has been and is favorable to liberal use of thiamin both in food and as a drug.

The argument runs that three causes operate to produce thiamin deficiency in the body: (1) low intake; (2) derangements of gastro-intestinal function which may diminish absorption; and (3) increased destruction or inefficiency of utilization in the tissues.

The fact that a large proportion of the total food calories is nowadays very often taken in the form of artificially refined foods containing little if any thiamin is unquestionable.

Whether a large proportion of people have abnormalities of digestion or metabolism which prevent their efficient absorption and use of thiamin, and therefore create a need for a large intake, is a medical question which reaches beyond the scope of this book. As bearing, however, upon the trend of opinion regarding thiamin intake, it may be noted here that the clinical reception of thiamin has been highly and widely favorable. Thus Vorhaus, Williams, and Waterman reported in the *Journal of the American Medical Association* of November 16, 1935, that in their hospital studies thiamin had improved 92 out of 100 cases of clinical neuritis, cured six and improved the other two of a group of eight cases of

*Reported in the *Journal of Home Economics* 31, 582 (October 1939).

unexplained gastro-intestinal hypotonicity, and improved the utilization of carbohydrate by six out of eleven diabetics.

The comprehensive and critical review of clinical experience up to 1938, given by Williams and Spies in their *Vitamin B_1 (Thiamin) and Its Use in Medicine* presents abundant evidence of favorable attitudes on the part of physicians.

It is now held that present-day habits of meeting the energy needs of nutrition so largely by sweets, fats, and breadstuffs and other cereal products from which nearly all of the thiamin has been removed, probably result in slight deficiencies which go unrecognized and by long continuance gradually bring about an ill-defined weakness. The suggestion of Sure, that failing health in the adult particularly may be the cumulative result of deficiencies in the diet covering a period of many years, is being widely quoted.

Williams and Spies (1938) also emphasize the view that deficiencies too mild to be recognized may nevertheless be cumulative in their weakening effects; that dietaries thus mildly deficient in thiamin have not only been common for the reasons already mentioned but also have sometimes unwittingly been prescribed by physicians and taught by dietitians, because special diets have often sought the avoidance of things deemed dangerous to the patient or difficult of digestion rather than the providing for all nutrient needs. Sometimes too, a diet followed because of a fear of digestive weakness is poor in thiamin and thus actually induces a slow degeneration of the digestive powers and perhaps also of the appetite. They hold that appetite and digestion may also be weakened by the circulation in the body of the unburned degradation-products of a carbohydrate metabolism insufficiently supported by the thiamin intake; and that in consequence of these "vicious circles" of digestive and metabolic influence many people are brought by imperceptible stages into a condition of thiamin need. They emphasize the broad range in which the person is free from symptoms and yet is not getting as much thiamin as they believe he should;

and they hold also that diets which are poor in other nutritional factors are apt to increase the body's need for thiamin.* In their view, "It is becoming more apparent that prolonged inadequacy of vitamins, either from dietary lack, failure of utilization, or increased demand, produces a variety of borderline states of ill health. . . . Clinicians are beginning to realize that the effects of a persistent, slightly faulty diet may not be detectable for years." . . . And moreover that, "Because of custom or preconceived ideas as to what foods are good for them, or because of dependence upon appetite as a guide to the proper selection of foods, many people are likely to choose a poorly balanced diet," even when poverty is not a factor in their food selection.

The British Medical Journal has pointed out editorially that in England the social custom of using the increasingly whiter bread which the present-day roller process of milling enables the baker to offer to (and urge upon) his public has resulted in the unjustifiable situation that even the comfortably circumstanced typical Englishman of today is getting less thiamin than the half-starved paupers of a century ago; for while the latter were given only a starvation ration it consisted largely of bread which had not been robbed of any of the natural constituents of the wheat.

Still more recently, the British quarterly *Nutrition Abstracts and Reviews* gives leading position to a review by Copping (1939) which (1) recognizes frankly the strength of of social custom and of the preference of the milling and baking interests for the products which are easiest for them, and (2) explains that the interest of the public health requires a modification of the fashion of extreme whiteness ("fineness") in flour and bread.

Copping concludes: (1) that the change from the formerly standard flour which contained more of the wheat to the present-day white flour has resulted in the reduction of the nutritive value of the protein, in serious lowering of the con-

*Williams and Spies 1938 *Vitamin B_1 (Thiamin) and Its Use in Medicine*, p. 58.

tent of calcium, phosphorus, and iron, as well as the nearly complete elimination of vitamin value . . . "all representing dead loss nutritionally"; (2) that in order to change back to whole-wheat flour it will be necessary both to educate the public and to overcome the inertia of the existing milling industry and flour trade; and (3) that "the advantages to be gained in national health would make it well worth while to overcome these difficulties."

Such natural foods as fruits, vegetables, milk, and eggs should along with the whole grain products be given reasonable prominence in the dietary. A two-fold recommendation aimed to accomplish this is: (1) that half the total calories of the diet be taken in the form of fruits, vegetables, and milk (including cheese, cream, and ice cream); and (2) that, of whatever breadstuffs and other cereal products one consumes, at least half should be in whole-grain, dark, or "unskimmed" forms.

It is *not* necessary or important, and it may be unwise, to make a special point of demanding that the socalled whole-wheat products be *literally* so. Often the manufacturing process begins by scouring-off and rejecting the more harshly fibrous extreme outer layer of the kernel, so that the resulting product, still containing practically all the nutrients of the grain, is less laxative and less liable to irritate the intestinal wall than a literally entire-wheat product would be. The possible danger of irritation is still further reduced if the grain, after having been thus freed from its scratchy outer coat, is then ground to small particles thereby diminishing the factor of mechanical stimulation of the digestive tract and increasing that of thoroughness of digestion.

Williams and Spies (1938, p. 110) suggest that there is probably a wide difference between the level of thiamin intake required for the prevention of beriberi and that which conduces to the most excellent health. With so strong a disposition to the liberality of intake as this view encourages, it would seem that it should be tested by experiments with laboratory animals fed different liberal levels of thiamin

throughout the lifetimes of at least two generations, as has been done in the study of calcium, and as is being done in the experiments with riboflavin referred to in the chapter which follows.

EXERCISES

1. Develop symptoms of thiamin deficiency in rats, pigeons, fowls or chicks by means of a diet deficient in thiamin.
2. What is the thiamin content of each of the dietaries or weekly food orders previously planned or recorded?
3. Arrange your "twelve to forty foods" in the order of their thiamin content: (*a*) per 100 grams of the edible portion; (*b*) per 100 Calories.
4. Which of the dietaries, and which of the individual foods, meet Williams' criterion of containing at least 1 milligram of thiamin per 3700 non-fat Calories?
5. In each of the dietaries what would the thiamin content be (*a*) if all the breadstuffs and cereals were "whole grain" products, and (*b*) if all were highly refined white products?

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Chapter XIII

RIBOFLAVIN, NICOTINIC ACID, AND THE PELLAGRA PROBLEM

Riboflavin

After yeast had been used for some years as an occasional experimental food in vitamin research, it was found to have a growth-promoting value (as an addition to certain laboratory diets) even after it had been heated to destroy its thiamin. Evidently it contained something of nutritional significance which is more stable toward heat than thiamin is.

This relatively heat-stable (thermo-stable) something was found also to be present, in relatively greater abundance than thiamin, in milk; and likewise to a very significant extent in egg-white, which contains only a doubtful trace of thiamin.

It had long been known that milk contains beside the orange-yellow fat-soluble substance which goes into the butter or cheese, a greenish-yellow water-soluble natural coloring-matter, which was first called lactochrome, and later *lactoflavin*. And this lactoflavin now turned out to have nutritional effects agreeing with some of those of the "heat-stable fraction" of yeast. The explanation of this was found to be that the individual substance *lactoflavin* is *one* of the relatively heat-stable factors contained in yeast, and in milk. This factor was also separated as a pure substance from egg-white and found to be chemically the same whether obtained from milk, or egg, or any of a number of other sources. Very soon too it was synthesized in the laboratory and its chemical nature fully established. (The structural formula is shown

on page 408 of the Fifth Edition of "Chemistry of Food and Nutrition" and on page 256 of the American Medical Association's "The Vitamins, 1939.")

Riboflavin is the name then coined to suggest as much of the chemical nature as a single short word can; and as being equally appropriate for the substance whether made synthetically or derived from any of its natural sources.

Riboflavin is widely distributed in both plant and animal tissues and is contained in relative abundance in milk and eggs, the means by which animals convey nutriment from one generation to the next.

The best known function of riboflavin is that it combines with phosphoric acid and protein to form tissue respiratory enzymes which control some of the oxidations involved in the life processes of the tissues.

The fact that riboflavin is an essential factor in the nutritional processes of all kinds of plant and animal tissues may reasonably be taken as implying two things: (1) that because of its wide distribution in plant and animal tissues, human dietaries are probably rarely so drastically deficient in riboflavin as they sometimes have been in thiamin or in vitamin C; and (2) that the unrecognized effects of shortages of riboflavin in man are doubtless more widespread in the body than the symptoms which have yet been established clinically.

The Journal of the American Medical Association has spoken of riboflavin as being "necessary for the maintenance of the defense powers of the organism"; and more recently Pinkerton and Bessey of the Harvard Medical School have reported* that riboflavin deficiency, even in a relatively early stage, greatly lowers the resistance of the rat to endemic typhus. They also point out that this type of deficiency offers a new method of approach to the investigation of other diseases, and of the ways in which bodily resistance to disease can be influenced through nutrition.

*Pinkerton, H., and O. A. Bessey, *Science* **89**, 368–370 (April 21, 1939).

In experiments with rats it has been found that riboflavin is essential not only to growth but also to normal nutrition at all ages. When the food is poor in riboflavin for any considerable length of time, digestive disturbances, nervous depression (different from the polyneuritis of thiamin deficiency), general weakness and lowering of tone, and an unwholesome condition of the skin are apt to develop; the incidence of infectious disease is likely to be increased, vitality diminished, life shortened, and the prime of life curtailed by the unduly early onset of the aging process.

There is strong scientific probability that the effects of higher or lower riboflavin intake upon the life-history will be similar in their general trend and significance in the human family to those observed in rat families which (with a uniform hereditary background and with environmental factors alike in all other respects) have been fed for two generations on dietaries of different riboflavin content. Such experiments by Ellis and others in the Columbia laboratories show that when account is taken of the full-life and successive-generation effects, increasing benefits continue to result from increasing richness of the dietary in riboflavin, up to levels more than twice as high as that of minimal adequacy.

Measurements and Requirements

Now that riboflavin is available in pure form, we no longer need artificial "units" for the expression of the amount of this factor contained in food or required in nutrition. Amounts can be expressed in terms of actual weight of riboflavin.

On the other hand we now know that riboflavin exists in plant and animal tissues, and thus in foods generally, both in the free state and in combinations of at least five to seven kinds. Hence the prospect of simple *in vitro* methods applicable to all kinds of foods seems somewhat doubtful at present. Meanwhile measurements are made by means of very carefully controlled quantitative feeding tests in which strictly comparable experimental animals on the same basal

diet receive their allowances of riboflavin (1) as known quantities of the pure substance or (2) as weighed feedings of the material under investigation, respectively. When such comparisons are made side-by-side under very carefully standardized conditions, over a sufficient range of intakes, and with sufficient numbers of animals at each feeding-level, it becomes possible to translate the results into terms of the actual riboflavin content of the food.

Investigation has shown that riboflavin is, in fact, the growth essential whose relative amounts had previously been expressed as "Bourquin-Sherman units of vitamin G" and Bessey has determined that one such unit is about 2.5 micrograms (millionths of a gram, sometimes designated gamma (γ) or μg) of riboflavin.

The standard allowances of Stiebeling and Phipard (1939)* may then be expressed as follows:

1,500 micrograms of riboflavin per day for girls of 14 to 19, for boys of 11 to 19, and for all people of 20 years and over;

1,350 micrograms for girls of 8 to 13, and for boys of 7 to 10 years;

1,125 micrograms for girls under 8, and for boys under 7 years of age.

And the standard of Rose's *Foundations of Nutrition*, Third Edition, becomes 50-60 micrograms of riboflavin per 100 Calories of food in family dietaries.

Some experiments have been made with riboflavin, on the same general plan as the studies with ascorbic acid described in Chapter XI, to ascertain the relation between the level of intake and the "saturation" of the body with the substance in the sense there explained. Hogan** suggests that one might estimate from such data that a man should for best results receive not less than 2 to 3 milligrams (2000 to 3000 μg) of riboflavin per day.

The experiments of Ellis mentioned above give strong

*U. S. Department of Agriculture, Circular No. 507, p. 66.

**American Medical Association volume "The Vitamins, 1939," page 279.

objective support to the presumption that bodily "saturation" with riboflavin is a condition favorable to the attianment of the higher levels of health.

At present, in fact, the scientific evidence for such a belief appears to be more conclusive in the case of riboflavin than in any other case except calcium and vitamin A.

Foods as Sources of Riboflavin

Plants form riboflavin beginning early in their lives. Even very young plants contain more riboflavin (in actual amount or in percentage of their dry matter) than the seeds from which they sprouted.

Somewhat as with vitamin C, though perhaps in a lesser degree, the young, juicy stage of development at which we most relish succulent foods for their "freshness" is also that at which they are the best sources of riboflavin. In general, too, the most actively functioning parts of the plant, the green leaves and growing tips, are relatively richest in riboflavin.

Reckoned on the basis of the 100-Calorie portion, citrus fruits (oranges and grapefruit) and bananas furnish their full quota of riboflavin toward the meeting of human requirements, while the scattering results on other fruits indicate that they furnish less.

The riboflavin contents of a number of typical foods are shown in Table 16, expressed on the same basis as are the corresponding thiamin values in Table 15 (preceding chapter).

Perhaps the most important general differences in the quantitative distribution of these two vitamins are, that milk is relatively richer in riboflavin while wheat is relatively richer in thiamin as are probably most of the seeds.

The green leaf foods, represented in Table 16 by kale and spinach, are also richer sources of riboflavin than of thiamin. Of the riboflavin content of fruits and vegetables generally we may say much the same as of their thiamin content, namely, that if the figures look low it is largely because of the high water content of these foods, and that when used as

abundantly as they well may be they become good sources.

Let us now consider some individual foods.

Beef and pork muscle, which will be remembered as differing widely in thiamin content, are seen to be very similar in the amounts of riboflavin which they contain. Liver contains, weight for weight, about ten times as much riboflavin as does muscle; and kidney is nearly as rich, in riboflavin, as is liver.

Milk, notwithstanding its high water content, contains about as much riboflavin, weight for weight, as do the muscle meats.

Eggs are distinctly richer in riboflavin than are the muscle

TABLE 16.—RIBOFLAVIN IN TYPICAL FOODS: MICROGRAMS PER 100 GRAMS

FOOD	RANGE WITHIN WHICH AVERAGE WILL PROBABLY BE FOUND
Foods of Animal Origin	
Beef muscle	180–260
Pork muscle	225–255
Kidney (of cattle and swine)	1700–2200
Liver (of cattle and swine)	1800–2600
Milk	195–240
Eggs	280–420
Egg white	150–300
Egg yolk	380–750
Grain Products	
Wheat, entire	100–220
Wheat germ	600–800
Vegetables and Fruits	
Banana	45–80
Broccoli	200–500
Cabbage	65–135
Carrots	75–125
Kale	400–600
Lettuce	100–240
Orange or juice	28–62
Spinach	250–400
Tomato	37–63
Turnip	50–100

meats. Even egg white, which contains only traces of thiamin, is a relatively rich source of riboflavin, though the yolk is still richer.

Whole wheat contains only about one-fourth as much riboflavin as thiamin. The germ or embryo is richer in both of these factors than is the entire grain. But as the germ constitutes only about two per cent of the weight of the grain, a large fraction of both thiamin and riboflavin of wheat is rejected with the bran, even if the germ is retained with (or returned to) the white flour.

Among the vegetables and fruits the green leaves are outstanding, kale and spinach containing several-fold more riboflavin than do typical fruits and other-than-green vegetables; while broccoli, cabbage, and lettuce occupy an intermediate place.

It is also of interest to see how different types of food compare as contributors of riboflavin (as well as of other nutritional factors) to representative dietaries.

Table 17 shows this as illustrated in Stiebeling's data for medium-cost dietaries as reported in the consumption studies made jointly by the Federal Departments of Agriculture and of Labor.

In these presumably representative cases, milk (including cheese and ice cream) was the largest contributor of riboflavin to the dietary; meat (including poultry and fish) was second; and vegetables stood third. The importance of the vegetables is not fully apparent at a glance in Table 17 because they are there subdivided. Eggs contribute as large a proportion of the riboflavin as of the protein, if the data of Table 17 are typical as we believe them to be.

Pellagra and Its Cure by Nicotinic Acid

The word *pellagra* signifies rough or inflamed skin. This is the outstanding symptom of a disease usually associated with poverty and with too great a dependence upon maize as a food. While pellagra is often called a disease of maize

TABLE 17.—RELATIVE PROMINENCE OF CERTAIN TYPES OF FOOD*
(in dietaries costing $2.38–$3.00 weekly per food-cost unit)

Food or Food Group	Percent of Food Money Allocated	Percentages Contributed by Each Food Group to the Total Secured					
		Calories	Protein	Calcium	Vitamin A	Vitamin C	Riboflavin
Meats and fish	25.5	12.9	36.2	2.7	7.1	0.7	32.2
Eggs	5.0	1.7	4.9	2.7	6.0	—	5.3
Milk, cheese, ice cream	12.1	9.8	16.0	60.7	13.9	5.3	34.2
Butter, cream	7.6	9.3	0.4	1.4	16.0	?	0.4
Other fats	3.0	7.8	0.5	0.1	0.8		1.1
Breadstuffs, cereals, bakery products	17.6	30.3	27.3	12.0	3.5	0.6	5.7
Sugar, sweets	4.2	12.4	0.1	2.1	—	—	—
Potatoes, sweetpotatoes	1.5	5.8	4.4	3.4	2.6	22.8	7.2
Dried legumes, nuts	1.8	2.9	5.3	3.4	0.2	—	0.8
Tomatoes	1.5	0.3	0.4	0.5	9.5	7.8	0.6
Citrus fruits	3.2	1.1	0.5	3.0	0.6	29.6	3.3
Green and yellow vegetables	3.9	0.8	1.4	3.4	33.7	12.8	3.7
Other vegetables	3.4	1.0	1.0	2.8	1.3	8.1	1.2
Other fruits	3.9	2.8	0.7	1.4	4.6	12.3	3.9

eaters this is to be taken in the same sense that beriberi is a disease of rice eaters. In each case the disease is to be attributed not to anything actively injurious in the food but to nutritional deficiency due to too great a dependence upon "one-sided" food,—food whose energy value is *not balanced* by sufficient amounts of other nutritional factors.

The pellagrin, as the victim of this disease is often called, usually suffers not only with the skin trouble which gives rise to the name but also with mental or nervous disorder or depression, and with inflammation of the tongue and the lining of the mouth often extending to severe disorder of the digestive tract. One sometimes hears reference to "the three Ds of pellagra—depression, dermatitis, and diarrhoea." It is also considered by physicians in pellagrous regions that

*Adapted from Stiebeling, Serial No. R 409, Bureau of Labor Statistics, U. S. Dept. Labor (1936).

when either the nervous (mental) disturbance or the digestive disorder occurs with the characteristic dermatitis, the two symptoms together justify a diagnosis of the disease. A characteristic feature of the dermatitis of pellagra is that it occurs symmetrically upon, for instance, the backs of the hands, the ankles, the forearms, or the back of the neck. Often but not always, the dermatitis is most pronounced on some part of the body which is exposed to the sun. In its early stages it may resemble sun-burn.

Not until the first decade of this century was pellagra reported in the United States. Then the reports of its presence rapidly grew to an alarming frequency, especially in the South. Authorities of the United States Public Health Service consider that probably over 100,000 of our people have suffered from pellagra in each of the past 25 or 30 years.

Naturally, this disease has been much studied. It was found that an analogous condition, called "black-tongue," in dogs could be induced experimentally by pellagra-producing diet, and cured by such dietary improvements as were found to cure clinical pellagra.

Late in 1937, it was found that nicotinic acid cures black-tongue, and immediately there followed a rapid succession of reports of its successful use in human pellagra.

The substance which thus unexpectedly acquired such important nutritional interest, had long been known to chemists; and one may readily "look it up" as fully as one desires in books on organic chemistry. It was first described as one of the products formed when nicotine is broken down by laboratory treatment, and in this way came to be called nicotinic acid.

Nutritional Requirement for Nicotinic Acid

As yet (1940) quantitative data on intakes of nicotinic acid relate chiefly to desirable dosages for the therapeutic treatment of patients whose bodies are doubtless abnormally depleted of this factor, rather than to normal nutritional

needs. Tentatively however, Elvehjem has estimated* that the average adult probably requires somewhere between 10 and 25 milligrams per day.

There is evidence that the level of concentration of nicotinic acid in the body fluctuates with the amount which the dietary or food supply furnishes, and also with the rate at which it is destroyed in the body. In these respects the case of nicotinic acid is somewhat analogous to that of ascorbic acid which we studied in Chapter XI. But whether it is desirable to keep the body as nearly "saturated" with the one as with the other is a question for much further research.

The Practical Prevention of Pellagra, and the Broader Nutritional Problem of which This is a Part

Recent clinical evidence seems to leave no room for doubt that while nicotinic acid cures the most outstanding symptoms of pellagra, the typical pellagrin is usually a sufferer from shortage not only of nicotinic acid but also of riboflavin and often too of thiamin.

Thus while riboflavin cannot prevent or cure pellagra without nicotinic acid, yet in practice the riboflavin content and the nicotinic acid content of the diet both have a bearing upon the occurrence and persistence of the disease. Liver and yeast, being relatively rich in both, naturally have a high place in therapeutic discussions of the disease. But such permanent and widespread reform of the food supply as is needed will probably be more effectively brought about in terms of the more staple or everyday foods of the general population.

The typical diet of the poor pellagrin consists so largely of pork fat, corn bread, soda biscuits and syrup, that it cannot be made nutritionally good by the addition of nicotinic acid alone. Even with the nicotinic acid it would also need fruits, vegetables, and milk in some form to increase its content of calcium, vitamins A and C, thiamin and

*Elvehjem, C. A. 1939 The vitamin-B complex in practical nutrition. *J. Am. Dietet. Assoc.* 15, 6-12.

riboflavin, and to improve the character of its protein mixture.

In 1932, careful studies of food supplies and dietary practices in relation to the occurrence of pellagra were made with Florida families by Sandels and Grady, and with South Carolina families by Stiebeling and Munsell. In both States it was found that the families successful in warding off pellagra used dietaries containing a much higher proportion of milk than did the families in which one or more cases of pellagra occurred. Sandels and Grady further found a significantly larger consumption of succulent vegetables, and indications of a larger use of eggs, cheese, and fruit in the families which escaped pellagra. Stiebeling and Munsell reported results of relief distribution of certain foods to poor families in pellagra regions, with results which "afford a practical demonstration" that the addition of 2 to 4 ounces of dry skim milk, 1 pound of evaporated milk, 1½ pints of canned tomatoes, or one-half pound of cured lean pork per person per day to the food supply "suffices to reduce greatly the incidence of pellagra among families which in times of stress subsist on a very monotonous and one-sided diet containing very little milk, lean meat, fish, or eggs."

Combining the findings of the United States Department of Agriculture and of the United States Public Health Service, it appears that any one of the following in the daily dietary is fully effective for the prevention of pellagra: a quart of milk or buttermilk; a pint of evaporated milk; one-third to one-half pound of dried skim milk, of lean meat, of canned salmon, of peanut meal, or of wheat germ; or one pound of fresh or canned collards, kale, green peas, or turnip greens; or two to three pounds of tomatoes, fresh or canned or as tomato juice.

The effects of liberal quantities of citrus fruit, already so abundantly produced in the South, and of such nuts as pecans and walnuts which could so readily be produced in larger amounts, have apparently not yet been investigated.

Pellagra-prevention campaigns in the South have empha-

sized the home production of vegetables and the keeping of cows and chickens. An effective combination of pellagra-prevention and nutrition education was found by the Red Cross in the plan of lending a cow to the poor country family until better health and resultant increased earnings made it possible for the family to buy one.

Sebrell writes* (1939): "The most important foods to add to the diet in (or for protection from) pellagra are milk, liver, lean meats, fish, eggs, tomatoes, green peas, and a variety of green and leafy vegetables, such as kale, mustard greens, turnip greens, and collards."

"It is very simple," he says in the same connection, "to state the remedy for endemic pellagra in this country. Here we have a rural disease known to be due to nutritional deficiency, caused by the cultivation of a money crop instead of food and forage crops. The remedy is obvious: The rural South must produce its own food supply."

For the large, low-income, majority of the rural people of the South this will mean the home-raising of vegetables and poultry and the keeping of a family cow.

EXERCISES

1. Arrange your "twelve to forty foods" in the order of their riboflavin content, (*a*) per 100 grams of edible portion, and (*b*) per 100 Calories.

2. On the above showing, which of these foods would you consider of most practical importance as sources of riboflavin?

3. Which of these foods are important sources: (*a*) of riboflavin and calcium; (*b*) of riboflavin and vitamin C; (*c*) of riboflavin and vitamin A?

4. Taking account of the quantities in which they enter into well-balanced dietaries, (1) what familiar foods equal milk in importance as sources of protein, calcium, and riboflavin? (2) And which foods equal oranges in importance as sources of vitamin C and riboflavin?

5. Explain to what extent you have, in answering the preceding question, taken account of the potential as well as the present place of oranges in the food supply. What can you tell of the trend of citrus fruit production and prices?

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*Sebrell, W. H. 1939 *J. Home Econ.* 31, 534.

6. Consult the most recent and authoritative medical publications available, as to whether the word pellagra now stands, (1) for nicotinic acid deficiency *simply*, with any accompanying riboflavin deficiency regarded merely as an accidental complication, or (2) for the full "disease entity" or "complete clinical syndrome" for which it has hitherto stood, in which while nicotinic acid controls the more outstanding symptoms riboflavin is also a factor in the prevention and cure of the disease.

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Chapter XIV.

OTHER WATER-SOLUBLE VITAMINS

Vitamin B_6

The chemical nature of vitamin B_6 was established early in 1939 and quickly verified by the chemical synthesis of the substance. References to the original evidence are included among the suggested readings listed at the end of this chapter.

At about the same time, vitamin B_6 was reported by Spies and his coworkers to be an essential factor in human nutrition. That shortages of vitamin B_6 actually occur in present-day human experience is indicated by Spies' finding that pellagra patients of a not unusual type, who had been cured of their outstanding symptoms by nicotinic acid, thiamin, and riboflavin, still suffered from vitamin B_6 deficiency and regained health rapidly when pure vitamin B_6 was given them.

In some aspects, at least, of its functioning, vitamin B_6 appears to be interrelated with the nutritionally essential unsaturated fatty acids. King, in an excellent review of the evidence available to the beginning of 1939, gives much weight to the work of Birch (1938) who concluded that both vitamin B_6 and a fatty acid or fat-soluble factor are concerned in the "acrodynia-like" dermatitis of rats; and that this latter factor is similar to the "fatty acid factor" of Burr and Burr and to the fat-soluble antidermatitis factor of Hogan and Richardson. Birch further suggested that the

function of vitamin B_6 may be connected with the utilization of the unsaturated fatty acids.

Schneider, Ascham, Platz, and Steenbock (1939) have reported a long list of foods, some of them fats and some presumably sources of vitamin B_6, as being potent for the prevention of the acrodynia-like condition. Still more recent work at Wisconsin (Schneider *et al.*, 1940) indicates that another, unidentified "B-vitamin" is involved along with vitamin B_6 in this type of skin disease.

Pyridoxine has been suggested as the permanent name for the substance hitherto known as vitamin B_6.

Pantothenic Acid, Factor W, and the Anti-grey Hair Factor

Recent research has indicated that the rat requires at least one, and probably several, "B-vitamins" in addition to those already discussed.

Pantothenic acid, so named by its discoverer, R. J. Williams, as indicative of its wide occurrence and presumably fundamental function, is, at the time this book goes to press (March, 1940), regarded as probably one of these factors. The recent report of a method for the synthesis of pantothenic acid seems to promise an early crucial test of this possibility.

Black, Frost, and Elvehjem (1940) find indications that another substance, designated as Factor W, is required by the rat for normal growth. This factor is evidently distinct from pantothenic acid.

Not yet clear is the relation to the above-mentioned of the agent which several groups of investigators have found to prevent the greying of the hair of black rats.

We have as yet no evidence as to the rôle of these factors in human nutrition.

Vitamins B_3, B_4, and B_5

The terms vitamin B_3 and vitamin B_5, for factors "of the B-complex" allegedly required by pigeons in addition to thiamin, were adopted prior to the recent research with other

species which has revealed the existence of so many nutritionally important "B-vitamins." Since the pigeon of late has been less used than mammals in nutritional research along these lines, the possible relation of the hypothetical vitamins B_3 and B_5 to the other better-known water-soluble vitamins remains in doubt.

Somewhat the same situation exists with vitamin B_4, a factor postulated some years ago. Later, many other investigators came to regard "B_4-deficiency" as either a chronic thiamin deficiency or a multiple deficiency involving several B-factors. The Wisconsin group, however, in 1936 presented new evidence of vitamin B_4 as a separate entity required for normal nutrition in the rat and in the chick; and a later paper (January 1939) from the same laboratory refers to a recently observed form of nutritional paralysis in rats as "quite probably the same as that observed in vitamin B_4 deficiency."

Vitamin H

The term "factor H" or "vitamin H" has been used in at least three distinct ways. A nutritive essential for trout was designated as "factor H" in 1928 by McCay and associates. Later, György used the term "vitamin H" for the hypothetical nutrient which prevents the so-called "egg white injury"; and Booher, for what now appears to have been the same substance as vitamin B_6.

Vitamins L_1 and L_2

Of the "lactation factors," L_1 and L_2, our knowledge is not sufficiently explicit to warrant discussion in this book.

Vitamin M

Day, Langston and coworkers found that monkeys require, for the maintenance of a normal condition of their blood, something that is contained in yeast and is different from any of the factors hitherto recognized. What other species need this vitamin M is not yet known.

Vitamin P (Citrin)

It has been thought by some investigators that the effect of citrus fruit consumption upon the permeability of the blood vessels involved more than could be explained in terms of vitamin C alone; so the presence of an additional "permeability factor," vitamin P, was postulated. The term citrin has also been used for preparations supposed to contain this factor.

Some other investigators have expressed skepticism as to the existence of any such "vitamin P" as a dietary essential.

At the time this is written (1940) both views are current in the literature, and the question must be regarded as open.

"Grass Juice" Factor

Work at the University of Wisconsin, confirmed by experiments conducted on quite a different plan at the University of California, indicates the presence in the fresh leaf juices of cabbage, lettuce, pasture grasses, and doubtless other plants, of a factor different from any of those hitherto recognized. It is still too early to judge (1940) how many species need (or respond favorably to) this factor characteristic of fresh succulent leaves.

EXERCISE

Making use of the library facilities available to you,* guided by *Chemical Abstracts*, *Experiment Station Record*, *Nutrition Abstracts and Reviews*, and the abstract sections of the *Journal of the American Medical Association*, the *Journal of the American Dietetic Association*, and the *Journal of Home Economics*, study the literature subsequent to 1939 of such as seem worth while of the vitamins mentioned in the foregoing chapter, and of any substances belonging to this category which have come into sufficient prominence since this text was written.

*To the Student.—It is consistent with the intention of the Exercise that you ask your librarian to borrow books from other libraries; but not that you deprive yourself of the experience of this search of scientific literature by trying to get the answer from another person.

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Chapter XV

VITAMIN A AND ITS PRECURSORS

General Relationships

Vitamin A itself is a colorless, fat-soluble substance found notably in milk, egg, and liver fats, and known to be essential both to the growth process and to the maintenance of normal conditions in the body at all ages. It has not been found in plants; but among the natural orange-yellow coloring matters of green and yellow vegetable tissues there are at least four *precursors* of vitamin A, *i.e.*, substances which give rise to vitamin A in the animal body. These are named alpha-, beta-, and gamma-carotene, and cryptoxanthin.

Structural formulas for vitamin A and for these four precursors may be found, if desired, on pages 352 and 353 of the Fifth Edition of Sherman's *Chemistry of Food and Nutrition;* but for our present purpose it will suffice to remember simply the existence of the precursors as a group. For convenience they are often referred to as "the carotenes," or even simply as "carotene."

While there are methods of making *in vitro* determinations of vitamin A and of "carotene" which serve certain special purposes, the only general basis of comparison between foods of all kinds or of summing up the contributions of foods of different kinds toward meeting the body's nutritional need, is in terms of *vitamin A values* determined by feeding experiments in which the body of the test animal converts the precursors into the vitamin in the same way and with essentially the same efficiency as does our own.

It has been reported that vitamin A occurs in two forms (vitamins A_1 and A_2), the one predominating in the liver oils of salt-water, and the other of fresh-water fish; but they seem to be very closely related and of essentially the same nutritional character and potency, so we treat the two as one in everyday discussions of food and nutrition.

FIG. 28. Photographs of twin brothers showing effects of different amounts of vitamin A in the food. (See text.) (*Courtesy of The Forsyth Foundation.*)

Vitamin A in Growth and Development

A good general first-impression of the significance of the level of intake of vitamin A to growth and development is afforded by the quantitatively parallel photographs of twin brothers shown in Fig. 28. At four weeks of age, which we take as representing the end of infancy in the rat, they were of the same size and indistinguishable in their appearance, both being smooth-coated, bright-eyed, alert, and of normal development for their age. From that time they were

fed the same diet except that one received butter and the other did not, though the latter had always as much as he wished to eat of a mixture of vitamin A deficient foods which were all perfectly good of their kinds. At the time they were photographed they had reached an age corresponding to about seven years in a boy. The one which has had plenty of vitamin A has continued to make a normal growth and development, while the one whose food has been otherwise adequate but very poor in vitamin A is stunted in growth and muscular development, is dim-eyed, and sadly lacking in alertness. Here the shortage of vitamin A had been so severe as to show its effects upon health as well as growth.

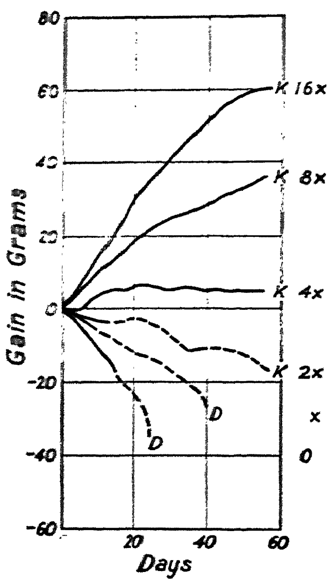

FIG. 29. Batchelder's average growth data from graded allowances of vitamin A.

In quantitatively controlled experiments with graded allowances of vitamin A* in an otherwise adequate and abundant diet, as in the experiments of Batchelder, the average growth data of which are summarized in Fig. 29, it may be clearly shown that even when there is no such severe shortage as to have any immediately visible effect upon health, the growth may still be limited by the level of vitamin A value of the dietary. In these experiments of Batchelder, for example, the rats receiving the 8x and 16x levels of vitamin A per day did not show any differences in ostensible health though the ones receiving the more liberal allowance of vitamin A were making better growth.

That such differences as were here induced by planned

*Indicated by multiples of x at the right-hand margin of Fig. 29, in which D = died; K = killed.

feeding of experimental animals may also occur as results of inadvertent shortages in the dietaries of young people, and may affect mental as well as physical development, is illustrated in the now classic work of Corry Mann with English school boys. This was not planned in terms of vitamin A alone, but as the nutritional benefits conferred by adding milk to the diet were also in large measure realized from the addition of either butter or watercress instead, it appears that vitamin A was a sufficiently potent factor to warrant consideration of his findings at this point.

Mann's work with these boys has outstanding significance because his improvements were effected in a dietary which at the start was already somewhat better than passable. It "had been chosen with every regard for the welfare of those who were to receive it" and "was medically adjudged to be adequate." Yet the results of Mann's controlled additions of milk, or butter, or watercress (green vegetable) to the dietary was so to raise the general level of the boys' health and vitality that they made better physical growth as shown by both weight and height, and better mental development as shown by a higher degree of alertness and scholastic ability and progress. The fact that this work was done under conditions which permitted of excellent scientific control and was managed and interpreted by judicially minded physicians, adds great weight to the conclusion that mental as well as physical growth and development, while already passably good at the beginning of the experiment and in the parallel control groups, was measurably improved by the addition of extra milk to the diet, and in only lesser degree by the addition of the extra vitamin A in the form of either butter or the green leaf vegetable.

Other evidence obtained directly from human experience, first clinically and then by carefully controlled experimentation, shows extremely important relations of the vitamin A value of the food supply to the functioning of the eye,—a fact effectively used by Hambidge to introduce his general summary, and by Booher and Callison in their chapter on

vitamin A, in the articles cited among Suggested Readings at the end of the chapter.

The sequence of the present text is first to describe the demonstration and measurement of vitamin A values as in controlled experiments with laboratory animals, then to summarize the effects of different levels of nutritional intake of this factor upon different organs of the body and upon the body and the life history as a whole, and finally to consider the quantitative aspect of the human requirement for vitamin A and the values of different articles and types of food as sources.

Demonstration and Measurement of Vitamin A Values

A litter of rats from three to four weeks old, and as uniform as possible in size and apparent health and vigor, affords a good starting point for the demonstration of the influence of differences in vitamin A intake, and of the principle of the feeding method for the measurement of vitamin A values.

When such rats are fed a diet well adapted to their needs in all other respects but devoid of vitamin A value, growth continues for a longer or shorter time according to the body-store of vitamin A possessed by the animal at the beginning of the experiment, which in turn depends chiefly (though perhaps not exclusively) upon the vitamin A value of the previous dietary of the rat, and of its mother. For the purpose of the present experiment it is expedient *not* to use animals from a family whose food supply is liberally fortified with vitamin A; for in such case their bodily stores may last them so long as to inconvenience the experimenter by the intervention of a long time before the appearance of the effect of the vitamin-deficient experimental diet. The time thus required to use up the surplus previously stored in the body is called the depletion period.

When the body is sufficiently depleted of its surplus vitamin A, growth ceases and (with animals as young as here described) usually a loss of weight begins within a few days,

and at about the same time careful examination may begin to reveal incipient abnormalities, or diminutions of positive health.

Animals thus continued upon the vitamin A-free diet (the basal experimental diet alone) *beyond* the depletion period are sometimes spoken of as "negative controls." In contrast, the "positive controls" are animals (otherwise strictly parallel, of course) continued on the same basal experimental diet as the test animals, but with a supplement of sufficiently high vitamin A value to permit them to make fully normal growth and development. Other animals of the group, separated at the end of the depletion period, may be fed different amounts of some material whose vitamin A value is known or is to be ascertained, and in the latter case the work must be so planned as to provide strictly parallel cases, in sufficient numbers, of animals fed the material under test and of those fed the "reference material" whose vitamin A value is quantitatively known.

The International Unit (I.U.) of vitamin A value is a value equal to that of 0.6 microgram of pure beta-carotene. The standardized carotene is prepared by the Health Organization of the League of Nations and is intended only for those having *official* need for it. A "reference codliver oil" whose vitamin A value has been compared with the International standard carotene is obtainable from the United States Pharmacopeia Organization, 43rd Street and Woodland Avenue, Philadelphia.

The United States Pharmacopeia (U.S.P.) Unit is so defined as to be identical with the International Unit. All of the numerical expressions of vitamin A value in this book are in terms of this unit.

As may be seen from Fig. 29 there is (when sufficient numbers of cases at each level are averaged) a fairly regular gradation of the weight curves according to the level of vitamin A fed; but the gain is, of course, not arithmetically proportional. The same data represented by this set of curves may be used to construct a "curve of response"

representing the relation between the different levels of feeding and the corresponding gains in weight during a feeding-period of any length that the experimenter may desire. A test period of four weeks is now most generally chosen. (Coward's book, listed among Suggested Readings, discusses these points in detail.)

At the upper levels of vitamin-A allowance, as for instance at the 8x and 16x levels of the experiments represented by Fig. 29, the animals (as in the similar work with thiamin described in Chapter XII) will probably appear equally healthy, with the difference in rate of growth and development as the only apparent result of the difference in vitamin A intake. At the other extreme, the negative controls sooner or later show evident illness with loss of weight and strength and development of one or more of the lesions mentioned in subsequent paragraphs as results of vitamin-A deficiency.

Nutritional Effects of the Level of Vitamin A Value of the Food Consumed

Rats of different colonies differ somewhat in the degree of shortage of vitamin A which must be imposed in order to bring about visible illness. It is reported from some laboratories that in order to keep their rats apparently healthy they must feed enough vitamin A to support a gain of body weight of about 5 grams a week; while the rats of the Columbia colony almost invariably remain healthy when receiving enough vitamin A to permit of a gain of 3 grams a week.

THE SKELETON, THE MUSCLES, AND THE SKIN

A higher level of vitamin A intake during growth induces the probability that at a given age the body will not only be heavier but also more long and lithe, with better-formed bones and teeth, better muscular development and muscle tone, and a superior condition of skin "like the sleekness of a well-conditioned farm animal," as was said of the boys who had extra vitamin A in the experiments of Corry Mann, mentioned above.

Even after such losses of the living impression as are involved in its transfer, first to the photographic plate, then to the engraver's block, and then to paper, the reader may be able to see something of this difference between the twin brothers shown in Fig. 28 (earlier in this chapter).

McCollum considers a certain dryness of the skin as one of the earliest indications of a shortage of vitamin A. The observations of MacKay upon babies of the London poor indicated that a mild shortage of vitamin A was retarding their growth and making their skin less wholesome and resistant. This condition she was able to cure, by enriching the diet in vitamin A, before the development of any of the more drastic symptoms.

THE EYE: XEROPHTHALMIA AND NIGHTBLINDNESS

In an experiment with laboratory animals such as was outlined above, xerophthalmia is usually the first noticeable characteristic symptom of the vitamin A deficiency. In work with cooperative human subjects a slight but detectable degree of nightblindness (difficulty of adaptation of vision to diminished light) is now regarded as the most delicate indication of an incipient deficiency of vitamin A.

The former is a special case of the general tendency of shortage of vitamin A to affect the mucous membranes, while the latter has to do with an independent function of vitamin A in the visual process.

Xerophthalmia (keratomalacia, conjunctivitis) is a condition of dry inflammation of the eye-lids and the outer surface of the eye which, soon after the discovery of vitamin A, was observed by Osborne and Mendel to be a frequent consequence of a shortage of this factor. The current explanation is that, under shortage of vitamin A, the cells of the lachrymal gland cease to pour out their normal secretion. The external eye thus becomes dry, bacteria multiply and are not washed away, the eyelids become congested and sometimes so swollen, sticky, and scabby as to close the eye. In extreme cases the cornea may be attacked and

permanent blindness may result. Mori observed such an eye disease among children of the Japanese poor and found that it could be cured (if not too far advanced) by chicken livers, fish livers, or codliver oil.

Excessive exportation of butter from Denmark during 1914-1918 caused shortage of vitamin A in the food of the poorer people with resulting high prevalence of xerophthalmia in Danish children as reported by Bloch and by Blegvad.

Nightblindness (hemeralopia), diminished ability to see clearly in a dim light, especially when the eye has recently been exposed to a bright one, is a defect of vision which has now been extensively investigated with results which show that vitamin A has a very fundamental rôle in the visual process, especially in the regeneration in the retina of the visual purple after its bleaching by bright light.

The chemical and physical mechanisms involved and the place of vitamin A in the process have been studied by several investigators including notably Hecht, Wald, and their respective coworkers. (To present this work in a fully explicit fashion would lead beyond the scope of this book. References to it are included among the suggested readings listed at the end of this chapter.)

THE RESPIRATORY SYSTEM

As Bessey and Wolbach (1938) explain, the characteristic histological changes of vitamin A deficiency, found in many epithelial structures, consist of: (1) atrophy of some of the normal cuboidal surface cells of epithelium, (2) reparative proliferation of basal cells, and (3) differentiation of this new material into a stratified keratinizing epithelium. Many of the visible pathological features of the deficiency in man and animals, they explain, are the results of accumulation of keratinized epithelial cells in glands and their ducts and in other organs. This is true of xerophthalmia, which has already been considered.

The distribution of such keratinizing metaplasia and the sequence of its development as between, for instance, the

eyes, the respiratory system, and the genito-urinary tract, tends to vary with species and perhaps also with the age at which the vitamin A deficiency is encountered. Bessey and Wolbach emphasize in 1938, as had Blackfan and Wolbach in 1933, the danger of vitamin A deficiency to the respiratory tract, and state that in the human infant the commonest and earliest appearance of epithelial metaplasia is in the trachea and the bronchi. Blegvad, following the histories of Danish infants who showed eye troubles due to vitamin A deficiency during 1914-1918, found that a large proportion of them ultimately died of respiratory disease.

THE GENITO-URINARY TRACT

Osborne and Mendel found that phosphatic calculi ("bladder stones") developed in the urinary tracts of a large proportion of their vitamin-A deficient rats. The explanations offered have not been entirely harmonious. In a comprehensive review Clausen concludes that the factors involved are not clearly defined. The hypothesis most consistent with known chemical and histological factors would seem to be that the precipitation of phosphate may be induced by a local infection which in turn is attributable to an abnormality of the epithelium resulting from the vitamin A deficiency.

Atrophy of the testes and disturbances of the female reproductive system due to the keratinizing metaplasia already discussed have been observed in vitamin-A deficient human beings as well as in experimental animals.

Storage of Vitamin A in the Body

Vitamin A can be stored in the body to a large extent, and with far-reaching results.

As Bessey and Wolbach summarize it, most animals have a remarkable capacity for such storage, "illustrated by the fact that a rat may in a few days store enough vitamin A to supply its nutritional needs for several months." Usually over nine-tenths of the body's store of vitamin A is found in the liver, the amount thus stored depending upon the

nutritional background,—how large a surplus the food has supplied and for how long. Lung and kidney tissue have much less than liver, but still measurable amounts; and it has been found that the level of vitamin A feeding influences the amount of vitamin A in the lung. Muscle contains so little as to be practically at the lower limit of measurability even when the level of nutritional intake of vitamin A is liberal. Adipose tissue may, however, contain a significant amount.

Agreeing fully with Bessey and Wolbach that the rat is able to store vitamin A in the body in sufficient amounts to meet nutritional needs for a relatively long time, we would also emphasize the fact that the limit of the body's capacity for storage of vitamin A is not quickly reached. Thus in one series of experiments* it was found that whether the opportunity for "saturation" was afforded by parallel additions of 1, 2, or 4 per cent of codliver oil to an already-adequate diet, or by feeding the diet fortified with 4 per cent of codliver oil for different lengths of time, in either case the body first stored rapidly from the surplus fed, but thereafter continued to add slowly to its store for as long a time as the experimental feeding was continued (and increasingly with the level fed up to the highest fortification here tried).

By the end of infancy, different individuals of the same species and racial stock or strain may have quite different bodily reserves of vitamin A. Thus, in the experiments summarized in Fig. 30, young rats of the same colony but whose family dietaries consisted of (1) one-sixth dried whole milk with five-sixths ground whole wheat (Diet 16) and (2) two-thirds dried whole milk with one-third ground whole wheat (Diet 70), respectively, were transferred at the age of 28 days to the same vitamin-A-free diet. Those from Diet 16 with its approximately minimal-adequate vitamin A content had only sufficient body store to grow about 10

*Sherman, H. C., and M. L. Cammack 1926 A quantitative study of the storage of vitamin A. *J. Biol. Chem.* 68, 69-74.

grams and to survive an average of 34 days, while those from Diet 70, which contains three to four times as much vitamin A as does Diet 16, had enough body store at the same age, to grow about 70 grams and survive an average of 65 days on the same vitamin-A-free diet. The difference in vitamin-A values between these two family dietaries is no greater than the differences which currently exist between many American families, and often even between families of the same locality and same economic level, depending upon their different choices of food.

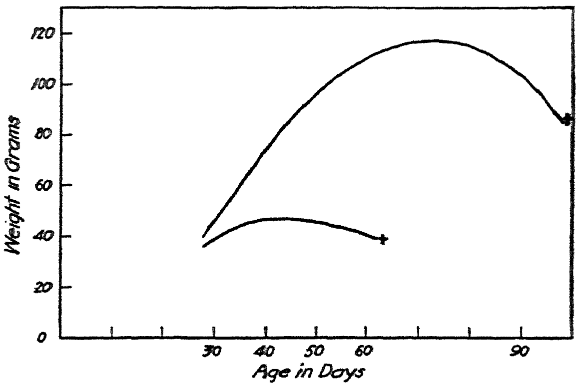

FIG. 30. Curves illustrating the effects of differing bodily stores of vitamin A. (See text.)

With older animals there is necessarily much less opportunity for growth to enter into the comparisons; but comparisons of rats taken at different ages from the same home dietary, which in this case had about twice the minimal-adequate level of vitamin A, showed that the length of time they could survive upon a vitamin-A-free diet continued to increase with their age up to adulthood. While this mode of investigation is in itself perhaps less clear-cut and conclusive than the one above described, it is significant as evidence of yet another kind that the body continues for a relatively long time to add to its reserves of vitamin A if the food contains a surplus above immediate nutritional need.

Lack of complete realization of the full extent and sig-

nificance of this phenomenon of bodily storage has undoubtedly sometimes been a cause of misinterpretation of human experience and undue skepticism regarding the importance of the vitamin-A level in the human food supply.

Considering the evidence now available on the quantitative rôle which body storage can play in the growth and health of the rat, and taking account of the relative lengths of life in the two species, it appears that human subjects would have to be kept for years under strict observation in order fully to control the differing influence from their different nutritional backgrounds.

Relation to Frequency and Duration of Infection

Summarizing his special study of the subject, Clausen points out that the possibility of diet having influence upon the incidence, course, and final outcome of infection, is a comparatively recent idea, a development of twentieth-century science. In other words, only as the means of investigating infections came to take on the character of the exact sciences, and as the newer knowledge of nutrition arose, did it become experimentally possible to find, and scientifically reasonable to accept, objective evidences of relationships which before, if postulated at all, had been regarded by physicians as merely the views of a few enthusiasts.

The work of Boynton and Bradford (1931), full reference to which the present reader will find at the end of this chapter, showed clearly that animals fed on diets low in vitamin A had very low resistance to experimental inoculation with infective organisms, and that this loss of resistance in rats deprived of vitamin A appeared before any other evidence of vitamin A deficiency. The fact that in this investigation rachitic rats showed undiminished resistance to infection is not necessarily inconsistent with the view that children who have been protected from rickets are less subject to respiratory disease; for protection from rickets has so generally been accomplished by means of the fish

liver oils that the children thus protected have at the same time received important additions to their bodily reserves of vitamin A. Mellanby, in the very careful and extensive experiments which he made at the time that vitamins A and D were just beginning to be differentiated from each other, observed that pups fed diets poor in vitamin A showed an undue liability to pneumonia. Rats of many different colonies and strains, observed under conditions of laboratory control, have been found by many investigators to suffer more from infections when kept on diets of low vitamin A value.

Discussions have not always distinguished between incidence, severity, and duration of infections. In one clinical investigation it was found that while extra vitamin A given to normally nourished people showed no certain effect upon the incidence or initial severity of "the common cold," it did measurably diminish the duration of infections of a given severity.

The work of McClung and Winters (1932) also showed clearly under well-controlled conditions a greater susceptibility to infection in those individuals whose diet is deficient in vitamin A.

Other (though not all) investigations indicate that, under conditions of everyday life, people receiving extra allowances of vitamin A have fewer days of disabling colds than in their previous experiences at the same season of year, *or* than in the parallel experience of people similarly placed in other respects but getting diets whose vitamin A value has received no special attention.

Doubtless the next few years will see further clarification of the questions which here we can discuss only in rather tentative terms or bring to notice through the suggested readings listed at the end of the chapter.

Meanwhile it seems safe to say that whether in a given case the benefit comes through diminished incidence, lessened severity, or shortened duration, there are doubtless many cases in which one suffers less from infections who has

regularly had a liberal daily intake and a rich bodily reserve of vitamin A.

Reproduction and Lactation

Vitamin A is quite as definitely essential to reproduction as is the socalled anti-sterility vitamin (vitamin E). The latter received this designation because it was not known to be particularly concerned with general nutritional functions and not because it is any more vitally concerned in reproduction than is vitamin A.

For the support of successful reproduction and lactation, the diet must furnish more vitamin A than is needed for even the most rapid growth. For instance, in the rat families studied by Sherman and MacLeod (1925) a diet of relatively low vitamin A value supported growth surprisingly well but failed utterly when put to the further and more rigorous test of its adequacy to the successful launching of a second generation. On this low vitamin A diet the females (although not showing any outward signs of vitamin A deficiency) either bore no young or failed to rear any of the few that were born, while in parallel families of the same hereditary background and with diets entirely similar except that they contained more milk-fat, reproduction and rearing of young proceeded normally.

Full-life and Successive-generation Experiments

The investigations mentioned in the preceding paragraph were extended by Batchelder in a series of full-life and successive-generation experiments with rat families fed diets of systematically graded vitamin A content. Those at the minimal adequate level of vitamin A intake grew to normal size (though in the lower ranges of the normal zone), were successful in bearing and rearing young, lived to an age within the normal range of longevity without showing any specific sign of vitamin A deficiency, and left vigorous offspring. On a level of vitamin A intake twice as high, the performances in all these respects were again within the

normal range, but the average record was slightly higher with respect to every one of the criteria just mentioned. Parallel animals on a level of vitamin A intake four-fold higher than that of minimal adequacy again made slightly better average records than those on the two-fold level. At a level eight-fold that of the minimal-adequate vitamin A requirement, the original animals showed no measurably different responses from those on the four-fold level; but the higher of these two levels seemed to confer a slight still further benefit upon the offspring.

To what extent the levels of concentration in the body of vitamin A (or of unchanged carotene, or both) vary with the levels of nutritional intake, and in what other ways, if any, the higher levels of vitamin A or carotene intake act to improve the chemistry of the body's tissues and fluids (the internal environment of the body) is still a research problem.

Whatever form the final explanation may take, the fact is shown by experiment for vitamin A, as for calcium and for riboflavin, that the difference between the minimal adequate and the optimal intake is much wider than had been supposed, or than is probable for many other factors in nutrition.

This means that the science of nutrition has greater constructive potentialities than hitherto supposed. Also, it meanwhile complicates the problem of quantitative standards of "requirement."

Human Requirements for Vitamin A

In view of the facts mentioned in the preceding paragraphs, the question, How much vitamin A value is required in human nutrition?, logically raises the further question, Required for what: for the maintenance of passable health with prevention of symptoms of deficiency, or for the support of the highest degree of nutritional wellbeing and positive health that each individual is potentially able to attain?

This distinction being relatively new, there are still many people, and perhaps even some influential ones, who regard it as more or less speculative. On the other hand, the reality of the difference is recognized as highly significant by those who study the experimental evidence quantitatively. Thus it is gradually coming to be considered that the human requirement should mean not only what is needed for the prevention of specific deficiency symptoms, but further, what is needed to permit a human population to realize fully the potentialities of its hereditary birthright.

The League of Nations is cited as authority for the view that vitamin A requirements for the adult may be safely met within a range of 2000 to 4000 I. U. per day; while Aykroyd and Krishnan,* as the result of special study, consider that the need for vitamin A (or carotene) is higher than previously believed, and propose allowances of 3000 to 5000 I. U. per child per day.

Booher and coworkers** found the minimum requirements for the maintenance of the normal efficiency of the eye in the dark-adaptation test in five "ostensibly healthy" adults (three women aged 30 to 40; and two men aged 21 and 25 years) to vary from 1750 to 3850 I. U. per day when taken in the form of vitamin A itself, or 3010 to 7210 I. U. per day when taken in the form of carotene dissolved in cottonseed oil.

When side-by-side experiments conducted in the light of recent knowledge show such a wide apparent range in even the minimum requirement, and it is still a matter of varying judgment among nutritionists as to whether the "optimal" or "socially justifiable" allowance shall be two, three, or four times the minimum, it is obvious that attempts to state human requirements in precise quantitative form must, for the present, be either individual judgments or conven-

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*Aykroyd, W. R., and B. G. Krishnan 1936 *Indian J. Med. Research* **23**, 741-745.

Booher, L. E., E. C. Callison, and E. M. Howston 1939 An experimental determination of the minimum vitamin A requirements of normal adults. *J. Nutrition* **17, 317-331.

tional compromises. Our own opinion favors the higher allowances.

Sources

The carotenes (and possibly other precursors or provitamins) formed in plants, and the ready-formed vitamin A contained in many materials of animal origin, together constitute the sources of the vitamin A which function so importantly in our nutrition. One may, therefore, give much weight to the vitamin A values of foods in the planning of the dietary, or one may leave the responsibility very largely to the regular taking of fish-liver oils which are many-fold richer in vitamin A than is the food mixture of even the most carefully selected dietary.

Probably the best plan is to give considerable weight to vitamin A values in the choice of foods or planning of food budgets, so that in satisfying our hunger we shall have ingested at least a minimal-adequate amount of vitamin A, and then for "insurance" or "good measure" or for the further promotion of positive health, take fish-liver oil also, at least during the winter months.

The green leaf vegetables as a group and such yellow vegetables as carrots and the highly colored varieties of sweet-potatoes are rich in carotene(s) and so are of high vitamin A value.

Grasses and other forage plants which (in America and Europe, at least) are not classified as human foods, are also of high vitamin A value, and in milch cows and laying hens the human family has very efficient servants for bringing into forms excellently adapted to our use (milk and eggs), the values of more fibrous leaves than we ourselves would care to eat. Muscles, however, take up extremely little vitamin A, even when the animal is abundantly supplied; so muscle meats are always of low vitamin A value. Liver is, weight for weight, usually a much richer source, but variable, depending upon how the animal has been fed.

The cereal grains, and therefore their mill products, and

bakery products (unless made with milk, butter, certain fortified margarines, or eggs) contain only insignificant amounts of vitamin A or of any of its precursors. This is also true of sweets and of most commercial fats and fatty oils.

So far, it has been possible to speak in general terms which are valid for general types of food. There are, however-

TABLE 18.—VITAMIN A VALUES OF CERTAIN FOODS

FOOD	INTERNATIONAL UNITS PER 100 GRAMS
Foods of Animal Origin	
Muscle meats	5–50
Kidney (of cattle, sheep, and swine)	500–1000
Liver (of cattle, sheep, and swine)	5000–10,000
Milk	160–225
Butter	3500–5000
Eggs	1000–2000
Egg white	negligible
Egg yolk	2500–5000
Grain Products	
Barley	71
Wheat	20–25
Wheat bran	138
Wheat flour	negligible
Bread	negligible
Fruits and Vegetables	
Apples	40–100
Asparagus	300–700
Bananas	160–400
Beans, baked	40–70
Beans, snap or string	600–1800
Carrots	2200–4000
Greens (Chard, Dandelion, Escarole, Kale, Lambs-quarters, Mustard, Spinach, Turnip tops)	13,000–27,000
Peas, fresh young green	1000–1300
Potato	30–50
Sweetpotato (varying with color)	1000–5000
Fish liver oils	around 200,000

ever, other foods which are too variable to be accurately covered by these general statements.

Thus not only is the vitamin A value enormously higher in carrots than in turnips; but also in deep-yellow than in pale-fleshed sweetpotatoes, in Hubbard squash than in pale-fleshed summer squash, in loose-leaf than in tightly headed lettuce, in the green growing tip than in the white stalk of asparagus, and so on in many other such cases.

Table 18 shows vitamin A values per 100 grams of the edible portions of typical foods. A corresponding table in which the data given are for 100-Calorie portions of food will be found on page 27 of Rose's *Feeding the Family*, Fourth Edition (1940). In the Appendix of that book, and also of this one, data for many additional foods will be found.

EXERCISES

1. Arrange your "twelve to forty foods" in the order of, or in groups according to, their vitamin A values, (1) per 100 grams; (2) per 100 Calories.

2. Divide a litter of rats between three and four weeks old into two groups as nearly equal as possible in size and in the distribution of the sexes. To one group feed a diet* adequate (to the needs of rats) in all respects, and with its vitamin A supplied solely in the form of butter or butter fat. To the other group feed a diet similar except for the substitution of lard or a cottonseed oil product for the butter or butter fat. Several weeks may elapse before the nutritional effects of this difference in diets begin to appear.

3. If circumstances permit, duplicate the preceding Exercise with a parallel experiment using a litter of rats whose home diet has been distinctly richer or poorer in vitamin A value.

4. Make "light adaptation" measurements with as many people as possible, and compare with their nutritional histories.

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Chapter XVI

RICKETS AND THE VITAMINS D

Straight, sturdy bones and sound teeth are among the most readily apparent and appreciated rewards of good nutrition. In an earlier chapter we have discussed the importance of providing liberal amounts of the inorganic elements which give these structures their characteristic strength and rigidity. Here we shall consider the rôle of a group of organic substances known as the vitamins D in assuring efficient utilization of the dietary calcium and phosphorus, in particular with regard to the development of normal bones and teeth.

Growth of Normal Bone

A detailed description of the physiological and histological processes of bone development would be inappropriate to this text. However, the relation of nutrition to these structures will become clearer if there is some understanding of the principal factors concerned in the formation of normal bone. Let us therefore consider briefly the sequence of events by which growth of a typical long bone is accomplished.

The main body or *shaft* of a long bone is known as the *diaphysis*. Separated from the shaft in young, growing individuals by a region of cartilage, but later becoming a part of the long bone, is a smaller bone, known as the *epiphysis* or *head*. Growth takes place by the continuous formation of new cartilage cells along the epiphysial margin. Normally, there is simultaneous degeneration of older cartilage cells

along the diaphysial border. The cavities so formed are invaded by blood vessels from the marrow of the shaft, carrying inorganic elements which are deposited as relatively insoluble salts (chiefly of calcium and phosphorus) in the *matrix* or intercellular substance of the degenerating cartilage cells, forming what is known as the *zone of provisional calcification*. Accompanying the blood vessels are cells known as *osteoblasts* (bone-formers) which surround themselves with socalled *osteoid tissue*, into the matrix of which inorganic salts are laid down to form true bone.

All of the factors determining the deposition of bone salt are not understood. It is known that calcification cannot occur unless adequate supplies of calcium and phosphorus are available. But it is also clear that growing bone must have some special property, not shared by body tissues in general, by virtue of which precipitation of "bone salt" from blood of normal calcium and phosphate content occurs in the bones but not in other tissues of the body.

The Nature of Rickets

Rickets is a condition, developing principally in infants and young children, in which the mineral metabolism is disturbed in such a way that calcification of the growing bones does not take place normally. In the majority of cases the failure of the bones to calcify appears to be due, not to any initial fault of the bone itself, but to some deficiency in the blood: for rachitic bones placed in normal blood serum usually begin at once to calcify; and a subnormal concentration in the blood of either calcium or phosphorus (or both) is generally found associated with rickets. However, Dr. Alfred Hess, one of the foremost authorities on the disease, observed indications that the primary deficit in *certain cases* of rickets concerned a *local* factor affecting the "anchorage" of the available calcium and phosphate in the end of the growing bone.

In rickets, the proliferation of cartilage cells and even of osteoid tissue continues, giving rise to a wide band of

epiphysial-diaphysial cartilage. Calcification, however, fails to occur, and consequently no zone of provisional calcification is observed. Since these proliferative tissues do not become properly hardened by the deposition of bone salts, the strain of bearing the body weight causes enlargement of the ends of the bones. This gives rise to the familiar enlarged joints and row of beadlike swellings at the rib junctions commonly called the "rachitic rosary," which are among the prominent clinical signs of rickets. As the disease continues there may be loss of already deposited mineral salts from the shaft, with consequent further weakening of the bones. "Knock-knees" or "bow-legs" commonly develop as the result of such weakness, and, for mechanical reasons, are apt to be especially severe in the heavy, otherwise well nourished infant and in the child who begins to stand at an unusually early age.

Although rickets itself is seldom, if ever, fatal, it may, unless treated, result in permanent deformities, which, besides their sometimes tragic effects upon the appearance and happiness of the individual, are often responsible for grave physical misfortunes. Thus, malformations of the pelvis as the result of rickets in early life may persist into adulthood and cause injury at the time of childbirth to mother or child or both. In the opinion of Hess, these "constitute the foremost burden of rickets on the community." There are also indications of a heightened susceptibility to respiratory diseases in severe rickets.

Discovery of the Antirachitic Factor

It has already been pointed out that the immediate cause of most cases of rickets appears to lie in a subnormal concentration of calcium ions or phosphate ions in the blood. Sometimes this low concentration may be traced to an inadequate mineral content of the diet. But, since mild rickets sometimes develops in infants fed almost exclusively on milk and thus liberally supplied with calcium and phosphorus, it is evident that the explanation of such cases

must be sought in some further factor or factors controlling the *utilization* of these elements. This aspect, which has figured prominently in the history of both clinical and experimental rickets, may now be considered.

Many investigators had noticed the prevalence of rickets among children living in dark, crowded quarters, and the greater incidence of the disease in winter than in summer; and as early as 1822 a Polish physician, Jedrzej Sniadecki, clearly stated his belief that the exposure of the body to direct sunlight was of importance in both the prevention and the cure of rickets (or *English disease*, as it was commonly called in that day).*

This view of the significance of sunlight did not receive general acceptance until years later. Many careful students of the problem felt rather that other hygienic factors were primarily at fault in the dark, unsanitary quarters where rickets was so prevalent. In 1890, however, Palm, an English physician who had practiced for some years in Japan, published the results of his correspondence with medical missionaries throughout the world to whom he had addressed queries regarding the occurrence or absence of rickets in their territory, the habits of the people, and the climatic and sanitary conditions. This remarkable survey revealed the complete absence of the disease in certain sections of the world where sunlight was abundant but where food and general hygienic conditions were extremely bad; and led Palm to the conclusion that the main etiological factor in rickets is a lack of sunlight.

About the time of the World War, pediatricians discovered that besides direct sunlight, artificial sources of ultraviolet light such as the mercury-vapor quartz lamp, were effective for the cure of rickets in infants exposed to them under suitable conditions.

At just about the same time, studies on experimental rickets were lending support to the theory that a dietary

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*Mozolowski, W. 1939 Jędrzej Sniadecki (1768–1838) on the cure of rickets. *Nature* 143, 121.

factor was involved in the prevention and cure of this disease. Dr. (now Sir) Edward Mellanby observed the development of rachitic symptoms in puppies on a restricted diet, and showed that codliver oil was very effective, whereas lard was entirely ineffective, in preventing these abnormalities of the bones. Various investigators in this country induced rickets in rats by feeding diets of severely imbalanced mineral content, and showed that this experimental disease also could be largely prevented or cured by codliver oil. It was soon made evident that the fat-soluble dietary factor or vitamin here involved was different from that already recognized as related to growth and to the prevention of eye-symptoms; for, as shown by McCollum, even after this latter factor (vitamin A) had been destroyed by bubbling oxygen through hot codliver oil, the oil retained its antirachitic properties. The term "vitamin D" was, therefore, adopted for the antirachitic factor.

The reconciliation of these two seemingly divergent views as to the rickets-preventing agent followed the discovery in 1924, independently by Hess and by Steenbock, that exposure of many food materials to *ultraviolet light* endows them with the nutritional properties attributed to *vitamin D*. To the substance originally present in the food which the ultraviolet rays "activate," the name *provitamin D* was given. Further experimentation showed that it or a similar substance occurs in the sebaceous secretion of the skin, and that when the skin is exposed to direct sunlight or other source of ultraviolet light this provitamin D, just as that in food materials, is transformed into vitamin D, which is in turn absorbed through the skin and distributed throughout the body, where it functions in exactly the same way as if it had been taken by mouth in fish liver oils or irradiated foods. Thus, the sunlight and the vitamin effects in rickets are but different aspects of the same phenomenon.

The statistics of rickets in Chicago which are cited in Rose's *Feeding the Family*, Fourth Edition (1940, page 170), illustrate the extent to which this' branch of the newer

Fig. 31. Three photographs of the right wrist of the same girl. The first shows active rickets with marked flaring of the end of the long bone and fringing where calcification is retarded. The second shows increased calcification as the result of codliver oil and sunlight. The third shows a normal density of calcification and a smooth end of the long bone when further treatment had completed the healing. (*Courtesy of Doctor Martha Eliot.*)

knowledge of nutrition has solved its problem, and also give reassurance as to the mildness of most of the rickets recently diagnosed. In the Chicago examinations of pre-school children during the years 1926 to 1932, from 21 to 16 per cent revealed evidence of rickets, but in 1933 only 13.7 per cent of the newly examined children showed signs of rickets, and in 1935 only 7.1 per cent showed any indications and only 0.03 of one per cent showed severe rickets. Thus the incidence of such rickets as is to be regarded as really a disease in the usual sense of the word has been reduced to three cases per ten thousand children. Or, as the same data might also be expressed, if we wish to know how many children nowadays incur severe rickets the total "rickets incidence" of present-day diagnoses may be divided by 200 (0.03 in 7.1).

Figure 31 shows x-ray photographs of the wrist of the same girl: (a) with active rickets of a degree now classified as "severe" (though not of such deforming severity as was common a generation ago); (b) when the rickets was healing; and (c) when it was healed.

Nature and Multiplicity of the Vitamins D

It is now well established that there are several vitamins D, two of which are important.

The provitamins which are converted to vitamins D by the action of ultraviolet light belong to the group of substances known as *sterols*, of which brief mention was made in Chapter II. Neither of the sterols occurring naturally in greatest abundance, *cholesterol*, found in animal fats, and *sitosterol*, in higher plants, is of significance as a precursor of vitamin D. But present in small amounts along with these are other, more highly reactive, sterols, notably *7-dehydrocholesterol** in animal fats and *ergosterol* in both higher and lower plants, which are changed on exposure to light of suit-

*For the sake of explicit identification of important substances a few somewhat technical chemical names are here given in the text. They need not be memorized. They may be found useful for reference in further reading.

able wave-length into potent antirachitic substances, designated, respectively, as *vitamin D_3* and *vitamin D_2* (or *calciferol*). These two products appear to be the forms of vitamin D of greatest importance in antirachitic foods and medicines, but they are by no means the only chemical substances which have the calcification-promoting properties ascribed to "vitamin D." Bills (1938) in a recent review (See Suggested Readings) lists ten sterol-derivatives possessing such properties in greater or lesser degree; and there is good reason to expect that further research will reveal still others.

Vitamin D_3 (activated 7-dehydrocholesterol) is the most prominent form of antirachitic vitamin in fish liver oils, irradiated milk, and irradiated animal products generally, and is believed to be the D-vitamin developed in the skin on exposure to ultraviolet light; whereas vitamin D_2 (activated ergosterol, calciferol) is the form widely used medicinally in preparations such as "viosterol," and is present also in irradiated yeast, and in the milk of cows fed irradiated yeast (sometimes called "metabolized" vitamin D milk to distinguish it from milks fortified with this factor in other ways). Eggs may contain predominantly either vitamin D_2 or vitamin D_3, depending on the feeding of the hen, but present trends in poultry husbandry are such as to increase the likelihood that vitamin D_3 will be the chief form present.

Chemically, vitamins D_2 and D_3 are very similar, as may be seen by comparing their structural formulae,* but inasmuch as the study of nutrition affords many instances where a very slight modification in the chemical structure of a substance profoundly affects its behavior in the body, it is pertinent to inquire how these two important vitamins D compare in nutritional effectiveness.

Investigation of the relative effectiveness of the two forms in man present great practical difficulties, which may suffice to explain the frequently divergent findings of even

*See, for example, Sherman, H. C. 1937 *Chemistry of Food and Nutrition*, 5th Edition, Chapter XXI.

careful and experienced investigators. Thus, as Park points out, since such comparisons must in the nature of the case be made directly with infants, there are inevitable limitations upon the numbers and uniformity of available experimental subjects, and upon the accuracy of control of experimental conditions.

Also such eminent pediatricians as Eliot, Jeans, and Park emphasize strongly the fact that the clinical signs of early or slight rickets are, as Park puts it, "notoriously deceiving and cannot be relied on."

Thus the further therapeutic study of the different vitamins D would lead beyond the scope of this work.

Rather, our present task is to consider the interrelationships of the vitamin factor with the factors of sunshine and of calcium and phosphorus metabolism in the nutritional support of skeletal development, including the formation both of sturdy bones and sound teeth.

Nutritional Rôle of Vitamin D

As already indicated, vitamin D (if for convenience we may continue to speak in the singular in dealing with this factor) came to be known and has been studied largely through its involvement in the rickets problem.

Rickets (*rachitis*) is a medical term which does not always have exactly the same meaning in medical literature. Pathologists have until recently tended to follow Schmorl in defining rickets in terms of the histology of the growing ends of the bones, while pediatricians have more largely followed Park in defining rickets as a condition of retardation (or suspension) of the normal calcification of the developing bone.

It is the more chemical and more nutritional concept of Park (rather than the older, more histological concept) which is generally followed in present scientific literature, and will be followed here.

As explained earlier in the chapter, the normal calcification (ossification) of the developing bone is essentially a

building into the cartilaginous bone matrix of the crystalline bone mineral for which the chief ingredients are the calcium and the phosphate brought by the blood.

When the normal calcification of the growing and developing bone is retarded, an analysis of the blood quite regularly shows a subnormal concentration of calcium (calcium ion), or of phosphorus (phosphate), or both. It is logical to suppose that this subnormal supply of ingredients brought by the blood is in some sense a cause of the retardation of the calcification (ossification) process, although, as already

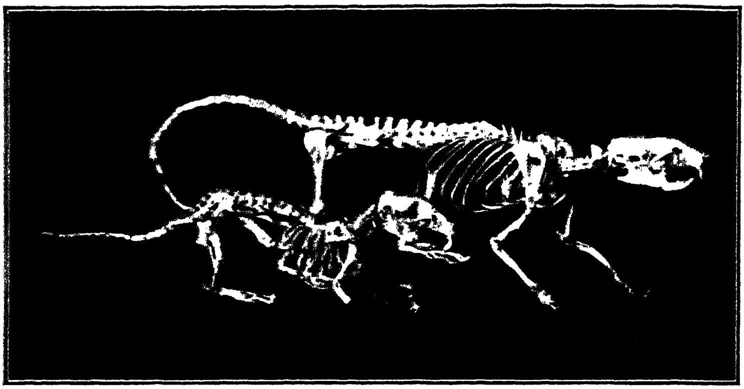

FIG. 32. Effects of very severe low-calcium rickets in contrast with normal twin brother. (*Courtesy of the* Journal of Biological Chemistry.)

mentioned, there may also (or in some cases) be a more "local" and less well defined factor involved.

This point of view recognizes both a low-calcium and a low-phosphorus type of rickets. Results of extreme (experimental) cases of low-calcium rickets are shown in Figs. 32 and 33. But only the low-phosphorus type shows the particular histology described in the classical work of Schmorl; so *some* writers have designated only the low-phosphorus type as true rickets.

How the subnormal concentration of calcium or phosphate ion in the blood comes about is not always clear. Such a shortage in the blood can sometimes but not always be attrib-

uted to a corresponding shortage in the food. More often, probably, it is attributable to a shortage in the amount of calcium or of phosphorus absorbed from the digestive tract.

Vitamin D, whether taken as such or formed in the skin by irradiation with light of certain wave lengths (in the ultraviolet), tends to restore to the normal the calcium or the phosphorus content of the blood, and the rate of calcification in the developing bone. This is the outstanding feature of the antirachitic effect or function. In just what ways the vitamin brings about the change in the blood-calcium or

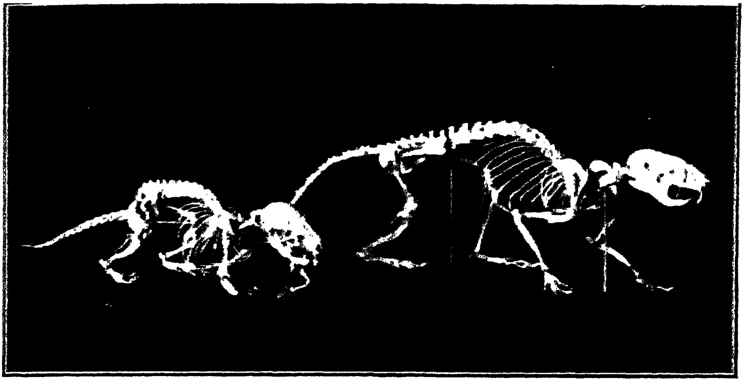

FIG. 33. Effects of very severe low-calcium rickets in contrast with a normal first cousin. Here with a dietary less drastically deficient, there appeared in the second generation the same skeletal difference as developed in the first generation in the case shown in Fig. 32.

blood-phosphate concentration, and whether there is, as the late Dr. Alfred Hess postulated, an additional local effect upon the "anchorage" of the calcium and phosphate ions in the developing bone, are still open questions. Doubtless the vitamin sometimes acts to increase the net absorption of calcium or phosphorus or both from the intestine. In some cases the vitamin seems also to "mobilize" calcium or phosphorus for the benefit of the developing ends of the bones even though this involves a diversion of nutrient material from some other tissue.

That so many of the mild cases of clinical rickets are of the

low-phosphorus type is largely if not mainly attributable to the fact that during the age-range in which rickets is most common there is a rapid growth of muscle and thus the baby's developing bones and muscles are competing for the phosphorus which the blood brings. To keep in mind the fact that a large proportion of the cases of the condition which we call by a pathological name (rickets or rachitis) may with at least as much reason be viewed as a matter of the relative rates at which two normal processes are proceeding, may serve greatly to clarify one's scientific view of the situation.

Severe rickets, while not fatal, may be a disease of tragic consequences; but at the other end of the scale (confusingly still called by the same name) are the "clinical signs" which "cannot be relied on" because in fact they are merely the signs that one physiological aspect of development is making slightly more rapid progress than another.

Perhaps the most helpful view is that presented by Jeans and Stearns in the 1938 meeting of the American Institute of Nutrition, namely, that children differ in the efficiency with which they assimilate the bone-building elements from their food, and that vitamin D in some way helps to improve the cases of low efficiency.

These investigators also emphasize the fact that even at levels above that of rickets prevention additional vitamin D may improve the rate of growth and development. This has also been found in controlled experiments with laboratory animals (Sherman and Stiebeling, listed in Suggested Readings).

Jeans and Stearns, in discussing their finding that amounts of vitamin D over and above those required to prevent rickets may have a further beneficial effect upon the retention of calcium and the linear growth of the bones, point out that this effect may not be noted in each individual but becomes evident when large groups are observed. Thus, studies of calcium retention in infants given no additional vitamin D showed marked variability in calcium retention with a low average. When amounts of vitamin D up to that supposed

to be sufficient to prevent rickets were given, the number of low retentions decreased, raising the average retention of the group. A further and significantly greater increase in average retention was obtained (again by raising the lower limit of the retention range) when two to three times as much vitamin D was given as is required to prevent rickets. Jeans and Stearns found similarly in older children, past the age where rickets is apt to develop, that some showed efficient utilization and others poor utilization of the calcium of milk when no added vitamin D was given; and that supplying vitamin D tended to improve the calcium utilization by the latter group whereas it had little effect on the former.

Measurement and Expression of Vitamin D Values

In brief, the usual measurement of vitamin D values depends upon the experimental production of rickets in rats, through feeding a diet devoid of this factor and with a severely imbalanced mineral content. When the rachitic condition has developed, certain of the rats are given the material to be assayed while other exactly similar animals receive doses of some standard source of vitamin D, both for a specified period of time and under rigidly controlled conditions. After this, both groups of animals are killed, a typical leg bone removed from each animal and sectioned, and the relative degree of healing determined by comparing the "*line*" or *zone of provisional calcification* brought about by the antirachitic factor administered during the curative period of the test. On the basis of this "line test," the vitamin D potency of the material assayed may be assessed in terms of the vitamin D potency of the standard reference source fed for comparison. In this country, the usual standard is the so-called U.S.P. Reference Cod Liver Oil distributed by the U.S. Pharmacopeia Organization (43rd Street and Woodland Avenue, Philadelphia); and when tests are made in strict accordance with the Pharmacopeia method a vitamin D value in terms of *U.S.P. units* is obtained. Another standard is a solution of irradiated ergosterol distributed by the Health

Organization of the League of Nations and designated as the International standard. The U.S.P. unit of vitamin D is defined as "equal in antirachitic potency for the rat to one International Unit of vitamin D as defined and adopted by the Conference of Vitamin Standards of the Permanent Commission on Biological Standardization of the League of Nations in June of 1931." For practical purposes, therefore, one U.S.P. unit of vitamin D is equivalent to one International unit.

Sources

Irradiation.—Herodotus wrote that sunshine is a potent factor in skeletal development; and an ancient Roman medical aphorism calls the Sun the greatest of physicians. But the importance of sunshine had to be rediscovered by Sniadecki in 1822 (as noted above), and again by Huldschinsky in 1919. When in 1924 it was found that natural foods, and (soon after) that certain sterols specifically, can be rendered antirachitic by irradiation, there rapidly developed a high enthusiasm for irradiated foods, and for irradiated ergosterol as a specific against rickets. But then (as explained early in this chapter) it turned out that the antirachitic substance produced by irradiation of ergosterol, or other plant sterol, is not the same as the natural vitamin D produced by irradiation of our skins or obtained from such animal sources as fish oils, egg-yolks, and milk-fat.

The fact that we do not get, as was supposed, the same substance by irradiation of ergosterol, or yeast, or cereal foods, as by irradiation of our skins (or as we get from animal sources) logically leads to some shifting of emphasis from the artificial vitamin D_2 to the natural vitamin D_3, and from the irradiation of our foods to the irradiation of our bodies,—with direct sunshine containing its natural proportion of ultraviolet rays or with its carefully determined equivalent. Ordinary window glass stops most of the ultraviolet rays; but special glass which transmits them is now made, and is used in the construction of lamps which

yield an indoor equivalent of "June sunshine" (*i.e.*, of the brightest natural sunshine, at ordinary altitudes, of our temperate zone).

The same rays which produce vitamin D in the skin also increase the circulation, thus bringing a fresh supply of the precursor into the skin-layers where the transformation is taking place, and carrying the new-formed vitamin D promptly away from any danger of over-irradiation and into the service of the body as a whole, and particularly of the bones and teeth.

Fish oils.—*Codliver oil* is outstanding in that it has been used as a remedy for rickets since the middle ages and is still universally prominent as a nutritional source of vitamin D. Liver oils from fish of the order Percomorphi (of which the blue fin tuna is a prominent member) are much richer in vitamin D, one of them having a reported concentration four hundred times that of ordinary grade codliver oil. As they are also very rich in vitamin A, such oils, available commercially as *Percomorph oil*, are becoming widely used. There are many persons for whom the fact that doses of this oil are measured in drops while those of codliver oil are measured in teaspoonfuls proves to be an irresistible advantage! *Halibut liver oil*, which is far richer in vitamin A than codliver oil, is only a few times more potent in vitamin D. For this reason, halibut liver oil to which viosterol has been added is frequently used where it is desired to give generous doses of both vitamins with a minimum volume of fishy-tasting oil.

The flesh of fish which contain much body oil, such as salmon, sardine, and herring, is a fairly rich source of the antirachitic vitamin.

Eliot, Nelson, and coworkers (see Suggested Readings) have shown that an enormous potential source of vitamin D exists in the fat of salmon livers together with that of such other edible material as is trimmed off in preparing the standard-sized sections of salmon for canning. This mixture of liver and body fat, called *salmon oil*, is found to be com-

parable with codliver oil in vitamin A, and superior to codliver oil in vitamin D content. Thus the salmon canneries of the Pacific Coast will be able to furnish, as soon as consumers will take it, a very large supply of an oil which appears to be at least as rich a vitamin-source as is codliver oil.

Liver.—The liver appears to be a principal site of storage of vitamin D in the animals commonly slaughtered for food; and the consumption of calf, beef, lamb, and hog liver may thus be expected to contribute to the body supply of this factor. However, the amounts of vitamin D in liver depend upon the dietary and other management of the animal, and may vary down to practically zero.

Eggs.—Hess showed in 1923 that the yolk of one egg contained enough vitamin D to serve as a daily allowance for the prevention of rickets in babies. The diet of the hens and the amount of ultraviolet light they receive both influence the vitamin D content of the eggs produced. In recent years the practical advantages of including fish liver oils or other sources of vitamin D_3 in the diet of laying hens have been increasingly realized and the practice has unquestionably resulted in bringing to the market eggs of higher average vitamin D value than those which proved such effective antirachitics in the work of Hess and of the Johns Hopkins pediatricians in 1923–24.

Milk and Its Products: "Vitamin D Milk."—The evidence varies greatly as to the vitamin D content of the fat of milk produced by cows on ordinary rations. *Vitamin D Milk* is the term generally used to indicate milk which has been enriched in its vitamin D value. Three methods of producing such vitamin D milk are in regular operation: (1) mixing into the milk a purified concentrate of natural (animal) vitamin D; (2) irradiation of the milk; (3) feeding irradiated material (usually irradiated yeast) to the cow.

The practice of enriching milk with vitamin D in one of these ways is regarded with favor by most physicians and health commissioners, and has been given preferential en-

dorsement by the Council on Foods of the American Medical Association in the following terms: "Of all the common foods available, milk is most suitable as a carrier of added vitamin D. Vitamin D is concerned with the utilization of calcium and phosphorus, of which milk is an excellent source. The Council has recently made the decision that for the present milk is the only common food which will be considered for acceptance when fortified with vitamin D."

Already "vitamin D milk" is on regular daily delivery along with other fresh milk in many localities; and also a considerable part of the canned and dried milk now offered in the retail market has been irradiated.

An influential proportion of (though not all) pediatricians prefer animal vitamin D to viosterol, and also consider that vitamin D is best assimilated when consumed dispersed in milk.

Requirements

It follows from what has been said above that no simple quantitative statement of the vitamin D requirement of human nutrition could represent any general consensus of opinion. The different forms of vitamin D in use may vary (and, if so, to an extent not yet definitely measured) in their efficacy in human nutrition, and even the same chemical form may have different efficacy according to the medium in which it is taken. There are also differences of view as to the extent to which the amount required for optimal growth exceeds the amount required for the prevention of rickets; and it seems certain that under the same conditions some children need more than others.

Experts in this field have suggested from 135 to 400 U.S.P. or International units per child per day when in the form of milk, and at least 600 units when the vitamin D is given in other forms.

To those readers who are interested in the question of human requirements for vitamin D the paper of Jeans and Stearns, listed among the Suggested Readings below, is especially recommended.

EXERCISES

1. Induce rickets in rats by means of the Steenbock rickets-producing diet described in the current United States Pharmacopeia; or that of Zucker and coworkers in the paper listed among the Suggested Readings below. Arrange, if possible, for x-ray photographs. Otherwise, begin the experiment while the rats are small and see whether the rickets becomes obvious to naked-eye examination, either of the live rat or of its skeleton.

2. Induce low-calcium rickets by diets of low-calcium foods without provision for vitamin D either as such or as light. Save the skeletons of such rachitic rats as a permanent exhibit.

3. Examine the literature since 1939: (*a*) for further evidence as to the relative values of vitamins D_2 and D_3 for children; (*b*) for advances in knowledge of any of the other vitamins D.

4. Compile and discuss current estimates of the vitamin D requirements of human nutrition.

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Chapter XVII

OTHER FAT-SOLUBLE VITAMINS

Vitamin E

Although vitamin E is one of the longer-known vitamins, its existence having been recognized in the early 1920's, it is still not possible to define clearly the rôle of this factor in human nutrition; and for this reason a brief treatment only of it is appropriate to this book.

At least two chemically identified naturally occurring substances (known, respectively, as α-tocopherol and β-tocopherol) as well as a number of related synthetic compounds possess the activity ascribed to vitamin E.

The vitamins E are fat-soluble materials, found along with the fats in grains, vegetables, meat, milk, and butter, and doubtless occurring very widely among food materials of both plant and animal origin which have not been artificially refined. Wheat germ oil is an especially rich source which is often used experimentally. A characteristic property of the vitamin is its rapid destruction when the fat with which it is associated becomes rancid. In many natural foods, the vitamin E is protected against such destruction by its occurrence with socalled antioxidants, substances which delay or prevent the auto-oxidation of fats and their resulting rancidity. Toward heating and many other adverse influences, the vitamins E are among the most stable of the known vitamins.

Deficiency of vitamin E in rats manifests itself characteristically by reproductive failure in both sexes. In the

deficient female, oestrus, ovulation, and impregnation of the ovum occur normally, but the fetus dies and is resorbed before maturity is reached. Treatment with vitamin E restores the ability of the female rat to bear normal young. In the male rat, on the other hand, deficiency of the vitamin may cause apparently irreparable degeneration of the germinal epithelium, with resulting complete sterility. The effects of a lack of vitamin E are not, however, limited to the reproductive behavior, nor to adult individuals. A relation to growth and to the nervous and endocrine systems has also been reported (see reviews by Mattill, by Evans, and by McCollum *et al.*, cited under Suggested Readings).

Although there has been experimentation with other species, definite proof of the requirement for vitamin E seems to have been advanced only in the case of the rat and the mouse. However, there have been reports by veterinarians of beneficial effects of wheat germ oil preparations on the reproductive performance of cattle and hogs; and experimental studies relating the vitamin E intake of hens to the hatchability of their eggs and the viability of the chicks that are hatched. On the other hand, there are indications that not all species require vitamin E for normal reproduction. Thus, Thomas and his associates produced several successive generations of goats on a ration containing insufficient vitamin E for reproduction in rats. In preliminary studies, these investigators also found that vitamin-E-deficient rations do not interfere with reproduction in sheep or rabbits.

The relation of vitamin E to human nutrition is, as already indicated, still uncertain, and in any case vitamin E is so widely distributed among different types of food that there should be little likelihood of its being a "limiting factor" in human beings. Consequently, it seems unnecessary and quite possibly misleading to lay emphasis on vitamin E in practical considerations of food values.

"Vitamin F"

The term "Vitamin F" has been used variously by different investigators, most recently to denote the nutritionally essential unsaturated fatty acid (or acids) of which mention was made in Chapter II. However, even this use has now been practically abandoned in scientific writings.

Vitamin K

Various investigators had observed that chickens on restricted diets show a tendency to subcutaneous and intramuscular hemorrhages associated with an abnormally slow rate of coagulation of the blood. The cause of this condition was shown in 1935 to lie in a dietary deficiency of a fat-soluble factor distinct from vitamins A, D, and E, for which the Danish investigators Dam and Schønheyder proposed the term vitamin K or "Koagulations-Vitamin." The blood of deficient animals showing delayed clotting was found by the Danish workers to have a lowered content of prothrombin but a normal concentration of the other blood constituents known to be necessary to the clotting process.* The addition of vitamin K to such blood *in vitro* did not affect either the prothrombin content or the clotting time; but feeding vitamin K to the deficient animal promptly restored its blood to normal.

From recent studies it appears that at least two forms of this vitamin (designated respectively as vitamins K_1 and K_2) occur naturally; and that a number of simpler substances possess the antihemorrhagic properties of vitamin K in lesser degree.

Although information regarding the quantitative distribution of this factor is still fragmentary, vitamin K appears to occur rather generally among a wide variety of food materials; and thus seems unlikely to prove of much significance in practical considerations of food values.

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*The student wishing to review the current theories regarding the process of blood coagulation is referred to recent textbooks of physiology, or, for a fuller account, to Howell, W. H. 1935 Theories of blood coagulation. *Physiol. Rev.* 15, 435–470.

Furthermore, it is not yet clear whether mammals in general must be supplied with vitamin K in their diet. The possibility has been suggested that they may derive vitamin K from bacterial synthesis in their intestinal tract. In either case, it appears that bile salts are necessary for, or greatly assist in, the absorption of vitamin K. For, it has been noted that when the flow of bile into the intestinal tract is prevented experimentally, either by diverting the bile to the outside through a biliary fistula or by ligating the bile duct, rats and dogs develop a tendency to bleed and a low blood prothrombin similar to the hemorrhagic condition induced in chicks by a vitamin-K-deficient diet. This condition may be relieved either by feeding bile salts (thus presumably enabling the animal to absorb more of the vitamin K in his food or intestinal contents) or by feeding massive doses of vitamin K (a fraction of which appears to be absorbed even in the absence of bile); but the most effective treatment is the combined feeding of vitamin K and bile salts. Such experimentally induced conditions are clearly outside the realm of normal nutrition; but are none the less of great interest in that a similar tendency to bleed and low prothrombin value has long been recognized in certain patients with diseases of the biliary tract. Now it has been found that this clinical condition frequently responds to the same measures as proved most effective in experimental animals with fistulas or ligations of the bile duct, namely treatment with vitamin K and bile salts.

EXERCISES

1. Study the available literature, particularly that published since 1939 when the foregoing text was written, upon one or more of the vitamins here mentioned, and others, if any, which may have been discovered since.

2. On the basis of the study just suggested, write a supplement bringing up to date the section dealing with the vitamin or vitamins thus studied.

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Chapter XVIII

SOME RELATIONS OF FOOD TO THE TEETH

Introduction to "the Tooth Problem"

The formation of good teeth, and the maintenance of the health of the teeth and gums, present such special and such baffling problems that any attempt to treat this subject here will necessarily lack conclusiveness of scientific explanation.

Yet while the teeth and adjoining tissues are quite unique structures they still are a part of the bodily structure, and like the rest of the body they are considerably influenced by the food.

Some relations of food to good teeth are now sufficiently established to warrant our attention, even though we have not yet a clear consensus of opinion as to the precise explanation of all of the facts.

Broadly speaking, a tooth is made up of three main sections: the *enamel* or outer covering, the *dentine*, and the *pulp*. In the perfect tooth, the enamel is hard, brittle, and semitransparent, and presents a smooth, lustrous appearance. It is non-cellular and is built up of prisms united by a densely calcified intermediate substance. The enamel forms a comparatively thin layer or cap over the dentine, which makes up the largest portion of the tooth. The dentine is a yellowish-white, translucent substance resembling bone, and consists of a non-cellular, homogeneous material traversed regularly by branched socalled dentinal tubes, which contain project-

ing outgrowths from the dentine-forming cells, together with nerves, some tissue fluid, and other organic matter. The innermost portion of the tooth, the pulp, is a soft tissue, composed largely of cells, blood vessels, and nerves. Its outer layer consists of *odontoblasts*, or dentine-forming cells; and in young, growing teeth there is always between the pulp and the (calcified) dentine a layer of uncalcified matrix, penetrated by fibers from the odontoblasts, which is the zone where further calcification is taking place. Normally, this zone is quite thin, but in an imperfectly calcified tooth, it may be wide and irregular and patches of uncalcified material known as "interglobular spaces" may remain as permanent defects in the resulting dentine. The imperfectly calcified tooth may also show defects of the enamel, varying from slight roughness to deep pits and grooves, and even in some cases to a complete absence of enamel over certain areas.

The term *hypoplasia* is frequently applied to such conditions of poor structural development of the teeth, which are to be distinguished from *dental caries*, or actual decay and disintegration of teeth already formed. The making of this distinction, however, should not be taken to imply that these two types of tooth trouble are entirely independent of each other, for even slight defects of structure may constitute a starting point for the development of caries. And complete perfection of tooth structure is not common.

Marshall (1939) considers it a "confirmed clinical and laboratory observation" that there is scarcely a tooth in man or lower animal which does not present areas of incomplete formation. Hence much depends upon the "personal equation" of the investigator in all studies of the incidence of tooth defects; for some will call a tooth defective while others, equally expert but of more tolerant temperament, will pass it as normal.

Marshall's view, following that of Fish, is that caries

begins in a permeable crevice or fault area which after eruption of the tooth becomes filled with the fluid and suspended materials present in the mouth, which from time to time include food particles and bacteria. Among the latter are those whose products tend to corróde the tooth. If this corrosion is not too rapid, the slight irritation of underlying dentine which it causes may result in a sufficiently augmented calcification from within to erect an effective barrier against further invasion of the tooth by the caries.

Although attempts have been made to study the incidence of hypoplasia as such in human teeth in order to correlate this with what was known of the nutritional background, these efforts have frequently been confused by the difficulty of recognizing hypoplasia in the presence of caries. In studying this aspect, therefore, frequent use has been made of the puppy as an experimental subject: for, as Blunt and Cowan point out, the dog (unlike the rat or the guineapig) resembles the human being in that he forms two sets of teeth, temporary and permanent, which in their growth and development are readily comparable to those of man. Also the puppy eats a mixed diet, similar to that of man, and he is, moreover, accustomed to living more or less indoors. Although hypoplasia resembling that of human teeth may be developed in dogs by dietary mistreatment, actual decay does not appear commonly in this species, and hence one may investigate the former condition practically uncomplicated by the latter.

Mrs. May Mellanby has reported extensive investigations of the teeth from the puppies with which her husband was studying experimental rickets. She found that those teeth and parts of teeth that were formed before birth were in general well calcified regardless of the diet of the mother; whereas those teeth or parts of teeth which did not calcify until after the young animal had become independent of his mother for food were normal or hypoplastic according as his diet was adequate or inadequate.

Some of the Causes of Tooth Defects

Because defects of structure are so closely connected with the caries problem, Marshall's classification, while offered in connection with his writings on caries, is broad enough for our present purpose. "For convenience" he groups the causes alphabetically as follows: A, anatomical; B, bacteriological; C, chemical; D, dietary; E, endocrine; F, failure in mouth hygiene; H, heredity. And he holds (1939) that the relative importance of these seven groups of factors varies "with age, environmental vicissitudes, habits, health, and probably other, as yet undetermined, agents."

Also it is to be remembered that these causes probably more often act two or more together than any one separately.

In fact the "chemical" causes are presumably results of bacteriological or dietary causes, or of such failures in mouth-hygiene as the use of corrosive dentifrices.

On the other hand, one may be born with some tooth defect or susceptibility to caries bacteria which cannot in any known way be connected with his heredity, and might therefore be classified as idiosyncratic or due to Chance (an alternative C for Marshall's classification in case you consider "chemical" as covered by other causes).

Empirical Evidence that Food is a Factor

Some years ago a group of diabetic children, who had long been receiving special care as to diet, were found to have unusually good teeth.

A large-scale trial with abundant controls was later made by feeding a part of the population of a large orphanage with a diet containing (as had that of the diabetic children) a more than average proportion of fruit and milk and a less than average proportion of sugar. This also led to a great decrease in the incidence of tooth defects among the children on the reformed diet as compared with the other children of like age in the same institution. Much additional evidence will be found in the Suggested Readings.

It may perhaps be of interest to add the following incident

which came to the knowledge of one of us while serving as a member of the advisory committee to a comprehensive dental research. One aspect of this research was to be a fairly large-scale attempt to improve the teeth of children in institutions, by certain nutritional enrichments of their dietary under conditions of experimental control, and with exceptionally careful and expert examination of the teeth before and after the dietary tests. A certain institution with a child population of about 400 seemed when first briefly visited to be a promising place for such an experiment because the physical circumstances permitted of good control, the management was scientifically-minded and cooperative, and the income of the institution was so meager that the proposed gift of "protective" foods for the nutritional experiment would have been extremely welcome. But the research dentist found in the first examination of these children's teeth that there was *so little room for improvement* that this group of children would not do for his investigation after all! And his explanation was that the institution, while financially in difficult circumstances, had for some years had a good dietitian so that the children had already had the benefit of the sort of diet he had intended to try,—and had only a fraction of the incidence of dental defects commonly found in American children of their age.

In this case the dietitian had been guided, not by any special theory as to the tooth problem, but by the general principles of the newer knowledge of nutrition. This institution population illustrated well the *trend* which Dr. Percy Howe expresses in the saying that, "*Generally*, good health and good teeth go together."

Undoubtedly, as the guidance of the newer knowledge of nutrition comes to be accepted more and more widely and wholeheartedly, dental health will be improved along with the health of the body as a whole. Yet we seem to meet enough people whose dental health is below the level of their general health, to constitute a scientifically valid indication that "there is something special about the teeth and gums."

Does study of them indicate need of special emphasis on certain nutritional factors? Does it also (as some investigators believe) indicate that diet has other than strictly nutritional relations to the health of the teeth?

Individual Nutritional Factors

Calcium and *phosphorus* are such prominent ingredients of the chief tooth mineral that they must certainly be regarded as among the major nutritional factors concerned in the building of good teeth. This must be emphasized; for the fact that these elements do not tell the whole story, and the further fact that, once built into the tooth structure, they are not very readily withdrawn by the circulation, have resulted in too great a tendency to ignore them in recent discussions of the tooth problem. For the construction of good teeth, the body needs, on the one hand, abundant supplies of calcium and phosphorus as building material; and, on the other hand, abundant supplies of at least three vitamins to regulate the processes involved in building these particular tissues.

Vitamin A.—Bessey and Wolbach, in the 1939 vitamin symposium of the American Medical Association,* give prominent attention to the view that vitamin A is an important factor in the formation of the teeth; and conclude from their study of the evidence that, "In all probability," vitamin A outranks all other vitamins in importance to the human being in the formation of good teeth.

Eddy and Dalldorf (1937, p. 49) referring, on the basis of the work of Wolbach and Howe, to the effect of a shortage of vitamin A as "the most important dental effect of any of the deficiencies," describe the result as an atrophy and metaplasia of the enamel organ in consequence of which there is deficient formation of enamel with a tendency to

*Bessey, O. A., and S. B. Wolbach 1939 "The Vitamins," a symposium arranged under the auspices of the Council on Pharmacy and Chemistry and the Council on Foods of the American Medical Association, p. 46.

exposure of the dentine and interference with a good formation of the teeth.

McCollum *et al.* (1939, pp. 603-606) consider that the enamel-forming cells (ameloblasts) are derived from the same embryonic tissue (ectoderm) from which gum epithelium has its origin, and although these cells are specialized for calcification they are, like epithelium in general, extremely sensitive to deficiency of vitamin A. McCollum holds that in the case of deficiency of vitamin A the enamel-forming cells become abnormal in appearance and instead of forming an even plane or curved surface they tend to buckle so that when the enamel is finished the surface presents an uneven contour "like a landscape of hills and valleys"; and that these cells, when inadequately nourished with vitamin A, do not lay down enamel of normal density, but rather an incompletely calcified enamel with interstices.

Vitamin C.—In the days when severe scurvy was common, it frequently resulted in loss of teeth, though available records do not make clear in how far this was due to an effect upon the tooth itself and in how far to the condition of the gums and jaw bones.

In 1919, Zilva and Wells in England studied microscopic sections of the teeth of guineapigs subjected to shortage of vitamin C and came to the conclusion that the tooth is one of the first, if not the first, of the parts of the body to be affected by subnormal intake of this vitamin, and that profound changes may occur in the teeth even when the ordinary scorbutic symptoms are still so slight as to be almost or quite unrecognizable. (There were at that time no means of measuring the level of concentration of vitamin C in the body.) The typical effect upon the teeth was described as a fibroid degeneration of the pulp with a replacement of the fine structural organization by amorphous material. They also found similar effects of vitamin C deficiency upon the teeth of monkeys. They therefore emphasized the view that subclinical conditions of shortage of vitamin C may be

more frequent than had been suspected and may reasonably be expected to injure the teeth.

Degeneration of the pulp tissue as a result of shortage of vitamin C has also been reported by several other investigators. In 1920 Howe of the Forsyth Dental Clinic and the Harvard Department of Pathology also found that scorbutic diets have a deleterious effect upon the teeth. He noted a marked decalcification and loosening of the teeth, with absorption of the alveolar processes as in pyorrhea; and emphasized the finding that if the condition was not too far advanced it could be cured by simple addition of orange juice to the diet. Others have also emphasized the good effects of orange juice upon the health of the teeth and gums. Höjer's very extensive studies, both experimental and clinical, seem to leave no doubt that even mild degrees of shortage of vitamin C are very important.

Recently, Boyle, Bessey, and Wolbach (1937) of the Harvard Dental and Medical Schools, in carefully controlled experiments with individual vitamin deficiencies, find that shortage of vitamin C may bring about a condition which upon full pathological investigation appears to be identical with one of the well-recognized clinical forms of pyorrhea: pyorrhea of the systemic type.

Particularly noteworthy is the further fact that these investigators then examined patients in the dental clinic and found definite correlation between this type of pyorrhea and a low concentration of vitamin C in the blood.

McCollum points out that dentine is derived from the mesoblastic tissue; and holds that the odontoblasts, which form dentine, are extremely sensitive to deficiency of ascorbic acid, so that if the tissues become depleted of this substance while the teeth are in process of growth, defective dentine will result.

Vitamin D.—The essential similarity between the various calcified structures of the body, and the demonstrated importance of vitamin D to the development of the bones, lead

naturally to the problem of the extent to which the teeth also are affected by this factor.

It has long been accepted that rickets occasions a *delay in dentition;* and Hess has cited an investigation in his clinic which showed that even in cases of extremely mild rickets teething was retarded, for "whereas about one-half the number of normal babies developed a tooth between the sixth and the ninth month, only about one-fourth of the infants with mild rickets had a tooth at this age." The eruption of subsequent teeth was likewise tardy. Clearly then the provision of vitamin D in sufficient quantity to prevent all rachitic manifestations may be expected to hasten somewhat the time of appearance of the baby's teeth.

Proceeding now to a consideration of vitamin D in relation to dental caries, two questions suggest themselves: (1) to what extent does hypoplasia (of which, as Mrs. Mellanby's experiments showed, lack of vitamin D is a prominent cause) predispose to caries; and (2) once the teeth have been formed (for better or worse), what protection, if any, against the inroads of tooth decay, may be hoped for from a liberal intake of vitamin D?

With regard to the first question, it would seem logical to expect that, whatever the underlying cause of caries, the damage, which involves essentially the solution of calcium salts by agents reaching them from outside the tooth, will be more severe to the hypoplastic tooth in which the protective coating of enamel may be less dense, or pitted and grooved (making mechanical removal of the destructive agent more difficult), or even totally lacking in spots; and in which the interglobular spaces of the dentine facilitate further penetration by the disintegrative fluid.

This reasoning is substantiated by the clinical experience that those teeth and portions of teeth which are in general most apt to be hypoplastic (perhaps because of the period of life at which they are calcified) are likewise in general most liable to dental caries. Thus, for example, Dick found

in an investigation of the permanent teeth that, of the cases with carious teeth, the lower first molar was decayed in 80 per cent and the upper first molar in 30 per cent. The fact that the lower first molars decay out of proportion to the others "is to be attributed rather to the main part of the enamel of the crown having been laid down in the first two years of life when rickety conditions are operative." And May Mellanby, correlating structure with decay in individual teeth, found that those which were normal or nearly normal in structure had carious cavities in only a little more than one-quarter of the cases, as compared with 85 per cent incidence of caries in distinctly hypoplastic teeth.

On the other hand, it is well known also that many hypoplastic teeth remain resistant to caries throughout life. Clearly, there are other factors to be considered in the problem of caries besides the structural quality of the teeth.

In the work of Boyd, Drain, and Stearns it appeared that a change of diet in the general direction indicated by the newer knowledge of nutrition reduced the rate of caries development in children, and that a further improvement was then effected by increasing the vitamin D intake by 600 units per day.

Favorable Effects of Certain Fruits and Vegetables

The eating of fruit, particularly raw fruit such as apple, or taking orange or grapefruit juice, at the end of a meal or soon after, or at bedtime, is considered by some investigators to induce "a bacteriostatic condition in the mouth."

Precise explanation of this benefit is not yet entirely clear. It may be a combined effect of several factors no one of which sufficiently predominates over the others to be readily demonstrated in an outstandingly convincing way.

In the case of such a soft-fibrous texture as that of a raw apple (or of celery) the mechanical effects of moderate massage of the gums, and of leaving the surfaces of the teeth scrubbed free from food particles, are in themselves beneficial. The "savory" property of such a raw food or of a

citrus fruit juice doubtless also means a physiological stimulation of the cells which pour their more or less bacteriostatic secretions into the mouth. Again, some investigators have emphasized the view that the mild acidity of a fruit or fruit juice is helpful in keeping the tooth surfaces free from plaques and in affording a wholesome stimulation of the mucous membranes of the mouth, in contrast to the unnatural and drastic "cleansers" of some tooth pastes, which may be injurious.

Fruits and vegetables generally, and milk, cream, and ice cream tend to the ensurance of good intakes of calcium, phosphorus, vitamin A, and vitamin C; while eggs are a good source of phosphorus, vitamin A, and vitamin D. Hence liberal use of these foods may reasonably be expected to aid both the development and maintenance of sound tooth structure and a healthy condition of the gums.

Drinking Water and Mottled Enamel

The discovery by Smith, Lantz, and Smith (1931) of the cause of mottled enamel is of closely related interest to the influence of food upon teeth and also illustrates the important fact that the methods of long-time feeding trials under strict laboratory control developed in recent nutrition research may also be uniquely useful in solving problems of the relation of our intake to our health which may be other than strictly nutritional.

Upon careful investigation by Margaret Cammack Smith, chief of research in human nutrition, University of Arizona, the defect of human teeth known as mottled enamel was found to be due, not to a nutritional deficiency, but to injury of the teeth by the fluorine of the local drinking water. Todhunter and Sparling reported in June 1937 that at that time 335 areas in 25 states, as well as localities in England, Italy, the Argentine, North Africa, China, and Japan, had confirmed the importance of this finding for the protection of the teeth of children born and reared in those areas.

In Conclusion

From the strictly nutritional viewpoint, there are at least five factors important to good teeth and gums: calcium, phosphorus, and vitamins A, C, and D. If much of the nutritional investigation of dental problems seems inconclusive, this is probably largely due to attempts to fasten upon *the* factor where in reality a combination of factors is involved. Approached more broadly the evidence is strong and fairly clear: such choice of food as the newer knowledge of nutrition teaches is unquestionably advantageous to the teeth.

There is also strong evidence that nutrition is not the only way in which food affects the teeth. Bunting and others emphasize the view that sugar in the diet not only lowers the intake of mineral elements and vitamins (by displacement of natural foods in meeting the calorie requirement) but also it promotes the multiplication of such bacteria as are specifically bad for the teeth.

Hence high intakes of protective foods and a low consumption of sugar are both important.

Drain and Boyd recommend that each child of 5 to 16 years be given daily: 1 quart of milk; 1 egg or more; 1 serving of meat, fish, chicken, or liver; 2 vegetables, half-cup serving of each; 6 teaspoonfuls of butter; 1 teaspoonful of codliver oil. For younger children, they recommend foods of the same nature, in appropriately smaller quantities in some cases. Such other foods as bread, cereal, and potato they would allow as additions to satisfy appetite and bring the dietary up to the needed total energy value; but not to replace any of the items specified above.

The Forsyth Dental Clinic is reported as finding that caries incidence decreased 79 per cent in that part of its child population which followed a dietary of the sort just outlined, while among children of the same age and locality on unreformed diet it increased 13 per cent.

Among the few conclusions which Marshall considers to be justified, by a critical examination of the extensive literature of caries up to 1939, is that dietary supervision has reduced

the number of carious teeth, and that the application of the newer knowledge of nutrition during pregnancy and lactation is beneficial to both mother and child.

Simmonds (1938) concluded from her study of the evidence regarding diet and dental caries, that the chief preventive measure against the caries is to reduce the consumption of sugar and other sweets to a minimum, and that next in importance is the cultivation of such habits in the choice of foods as shall ensure a regular nutritional intake of the essential mineral elements and vitamins "in abundance."

EXERCISE

After study of the available literature, including that later than the suggestions listed below, write a paper of about 1000 words supplementary to the foregoing chapter.

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Chapter XIX

NUTRITIONAL CHARACTERISTICS OF THE CHIEF TYPES OF FOOD

The purpose of this chapter is to review briefly the chief types of food as to the more significant nutritive values of each; and in conjunction with the following chapter to consider how a greater or lesser degree of prominence of a given food or group of foods may be expected to influence the nutritive value of the dietary as a whole.

Breadstuffs, Breakfast Cereals, and Other Grain Products

Bread is still the staff of life in the sense that an overwhelming majority of the world's people subsist more largely upon products of the cereal grains than upon any other one type of food.

Per capita consumption of bread and flour in the United States has declined somewhat during the past generation, (1) through partial replacement by other foods, and (2) through the lowered per capita need of total food calories because of the use of labor-saving machinery both in industry and in agriculture. Yet the breadstuffs and other cereal products still supply us about one-third of the total calories we consume, while in Europe the proportion is somewhat larger, and in Asia much larger still, though in tropical Asia rice tends to predominate over wheat and bread as the most popular means of meeting the greater part of the energy requirement.

Breadstuffs and other cereal products also contribute more largely than is generally realized to the protein supply.

This is shown, for example, in a series of 224 studies of presumably typical American families representing all parts of the country including both urban and rural conditions, and with due representation of the different economic levels. Here, in round numbers, the grain products cost 18 per cent of the total expenditure for food and furnished 38 per cent of the total calories and 37 per cent of the total protein. They were also estimated to furnish 30 per cent of the total phosphorus and 25 per cent of the total iron. Clearly our breadstuffs are economical sources not only of food calories, but of protein, phosphorus, and iron as well. On the other hand they furnish less than a proportionate share of calcium; and of most, if not all, of the vitamins, this latter depending upon the milling process to which the grain is subjected. Even the whole grain is negligible as a source of vitamin A and practically devoid of vitamin C unless sprouted. Of thiamin the whole grain contains a good proportion, and of other members of the "vitamin-B group" the whole grains are doubtless significant sources though these factors have not yet (1940) been studied quantitatively to any such degree as has the thiamin content.

At present there is a general trend toward a wider and larger use of milk, and especially of skimmilk powder, in breadmaking. Addition of significant amounts of skimmilk solids obviously enriches the bread in its protein, calcium, and water-soluble vitamin values. According to Prouty and Cathcart (1939) a considerable proportion of the white bread now made in the United States contains enough of milk solids to give it a calcium content at least twice that of white bread as made previously. Another means of vitamin enrichment is proposed in the use of yeast of especially high vitamin content. At time of writing (1940) this suggestion is too recent for us to judge whether or not it will materially modify the general nutritional character of the bread supply as a whole. There is also some discussion of the possibility of adding thiamin (and perhaps also riboflavin) in pure form to white flour. Always, it is obviously open to the consumer

to demand a flour or a bread containing a larger proportion of the nutritional constituents of the wheat kernel,—either a product to which the wheat embryo has been returned or (better) an approximately whole-wheat product. Breakfast cereals made from essentially whole wheat are already widely popular.

The breadstuffs and other grain products are popular both because, if well chosen, their nutritive value is important, and because their texture is favorable to the process of digestion. In their recent study of about 4,000 family food records representing eight major geographical regions of the United States, Stiebeling and Phipard (1939) found that, "In all regions and whatever the level of food expenditure, the largest share of the calories was derived from grain products."

Milk

Milk should be regarded as standing in a class by itself in its economy and efficiency as a means of making good the calcium and vitamin deficiencies of the cereals and in so supplementing their proteins and their general mineral content as to make a better-balanced food mixture than can be made from any of the grain products themselves.

It has been well said that, "The dietary should be built around bread and milk."

The science of nutrition has been teaching this for at least thirty years, the findings of recent years adding more reasons than were formerly known, and thus justifying increased emphasis upon the desirability of giving to milk a still higher place in the average dietary and in the total food supply.

Greater prominence of milk in the food supply of the individual, the family, or the nation means enrichment of the diet in its calcium content, and practically always in its riboflavin content and vitamin A value also. And these are the nutritional factors which we know with most certainty to possess large areas of beneficial increase above the level of mere adequacy. Thus milk is the food most likely to be

effective in meeting the actual need of a deficient diet; and also when the diet is already adequate, milk is the food most likely to be effective in building to higher levels of positive health.

Because, for Americans at least, the calcium intake depends chiefly (Fig. 34) upon the consumption of milk in some form (including cheese, cream, and ice cream), and because calcium is probably more often deficient in the dietary than

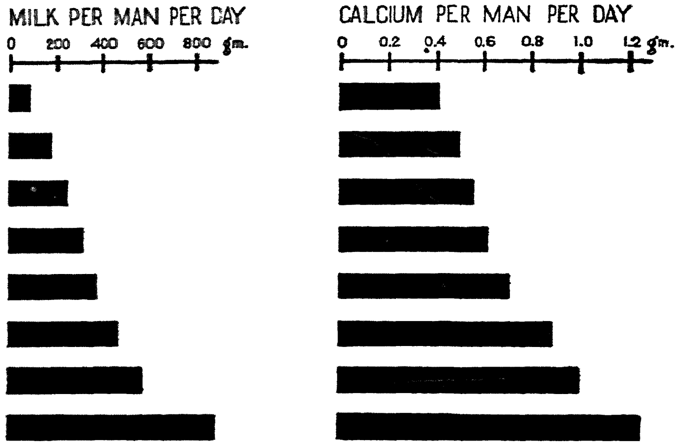

FIG. 34. The relation of milk consumption to the calcium content of the dietary. Here the 224 American dietaries previously mentioned were arranged in order of milk consumed and their calcium contents averaged in eight groups of 28 dietaries each.

any other chemical element, and certainly falls below *optimal* amount in most present-day dietaries, the explanation of the importance of a liberal use of milk tends to be given largely in terms of calcium. That milk is a highly evolved vehicle for meeting the calcium need in nutrition is further illustrated by the fact that its other constituents are such as to enable it to convey calcium with outstanding efficiency, a quart of milk actually containing more calcium than does a quart of limewater (saturated solution of calcium hydroxide).

But it must never be supposed that the calcium tells the whole story. For milk contains all the factors known to be needed in the nutrition of the mammalian species, and doubtless contains also any such essential factors as may be still awaiting discovery.

Milk is the one article whose sole function in nature is to serve as food, and the one food for which there is no fully satisfactory substitute.

Mrs. Rose writes:* "No other food can so well serve as the foundation of an adequate diet, because no other reinforces (the diet) at so many points." And again,** "Milk is particularly adapted to offset the total lack of minerals in fats and sugars, and the serious mineral deficiencies of white flour, hominy, polished rice, and other refined cereal products so widely used in American dietaries."

The doubt as to whether milk is a natural food beyond the nursing period is completely resolved by even a moderate knowledge of human evolution. By the use of the milks of other species in addition to breast milk it became possible for the human family to make use of what has been called "prolongation of infancy" but is better called "prolongation of the period of development and capacity to learn." Milk is, for the human species, therefore, a natural and logical food for a learning period which we now aspire to extend throughout our entire lives!

The milk of different species differs somewhat, and some methods of preserving milk may diminish its vitamin C and, perhaps in less degree, its thiamin content; but all the recognized or commercial forms of milk resemble each other much more closely than does any other food approach milk in nutritional characteristics.

In addition to the outstandingly efficacious amino-acid make-up of its natural mixture of casein and lactalbumin, milk also has other nutritional characteristics which in the long course of mammalian evolution have become fixed,—

**Foundations of Nutrition*, 3rd Ed., p. 389

***Ibid.*, p. 391.

doubtless because of their "survival value" in the promotion of growth and development, health and efficiency.

Its uniquely rich content of highly dispersed and thus readily assimilable calcium has already been noted. This makes it the most advantageous food source of calcium for the high calcium needs of the body which are fairly obvious during the period of the growth and development of the skeletal system (including bones and teeth); and, while less generally recognized, are important also to adult vitality and "the preservation of the characteristics of youth." Phosphorus also is contained in milk in exceptionally assimilable forms and in an amount which makes milk an important source of phosphorus of good calcium : phosphorus ratio. Most of the other mineral elements are contained in milk in proportions corresponding closely with the needs of human nutrition; in other words milk has among its nutritional characteristics a uniquely well balanced mineral content. The only important exceptions (so far as known) are iron and copper which nature conveys from mother to young more largely before birth and less largely through the mammary glands. That is, the iron and copper contents of milk are low, but correspondingly the baby is born with a reserve store of iron and copper in the body, largely in the liver.

Also, as was emphasized by the late Dr. Mendel, milk contains all the known vitamins, and while not all of them are present in milk in as high a proportion as we want them, it is probable that milk contains a larger number of the vitamins in reasonably well-balanced proportions than does any other one food.

Our information is not yet complete as to which of the nutritionally important constituents of milk are present in proportions (concentrations) well stabilized by nature, as are the proteins and calcium and phosphorus; and which fluctuate more with the level of intake of the lactating mother or the milch-animal, as do the vitamin C and vitamin D contents of milk. Steenbock and coworkers concluded from their experiments with thiamin that, in respect to this

particular vitamin, the upper but not the lower limit of concentration in milk is "under physiological control." This means that when the cow's ration is enriched in thiamin, the thiamin content of the milk does not rise above normal levels; but when the ration is impoverished, the thiamin content of the milk may become sub-normal.

While sub-normal levels of vitamins A, B (B_1), and C in milk have all been produced experimentally, the rations used to induce them are such as are known, if long used, to diminish the productivity of the cow, so that dairy farmers have no desire to use them. Hence in practice few cows are so fed, and those that are do not yield enough milk to have much influence on the quality of the market supply. The modern farmer feeds his milch-cows vitamin-rich rations the year round. Thus milks of sub-normal vitamin A, B, or C value are less common in the market, and commercial winter milk is more like summer milk, than the scientific literature might lead one to expect.

Physical properties of milk have also some nutritional significance: only two of these need be mentioned here. The fact that the fat is present in an emulsified form makes it more readily assimilable than are most other food fats except those of eggs. The fact that milk coagulates in the stomach is, on the whole, distinctly advantageous to the digestive process, especially when the milk is sipped in the course of the eating of solid foods. But for some (not all) infants and invalids, there may be a slight advantage in the use of milk which forms curds of a more flocculent kind. Such "soft curd milk" is now produced commercially in two ways: (1) by selecting cows whose milk naturally forms curds somewhat "softer" than the average, and marketing the milk of such cows unmixed with that of others; or (2) by treating ordinary market milk with an artificial process which "softens" its curdling property, largely by removing a significant part of its calcium. It is the responsibility of the physician to decide in the individual case whether an infant or an invalid

will gain any such advantage from the softening of the curd as to compensate for a reduction of the calcium intake.

Meats and Fish

In view of the high dietary place given to meat by most people who can afford it, one who seeks thoroughly to assess the basis and wisdom of the traditional and economic place of meat in American and European food supplies cannot but be strongly impressed by the lack of comprehensive studies carried out by the newer methods of nutritional research. Several papers have been published in which present-day methods have been applied to the answering of particular questions, but we have seen no record of any study of the nutritional place of meat in the diet at all comparable in comprehensiveness and convincingness with the investigations which have been made upon milk.

In the average of the above-mentioned 224 dietary studies representing all parts of the United States and various economic levels, meats (including fowl, fish, and shellfish) represented 32 per cent of the expenditure for food, and furnished 19 per cent of the calories, 35 per cent of the protein, 26 per cent of phosphorus, less than 4 per cent of the calcium, and 30 per cent of the iron.

Meats vary greatly in fatness, but are rich in protein or fat or both.

The proteins of meat are somewhat similar to those of milk in their amino-acid make-up, and therefore in the efficiency with which they supplement the proteins of bread and cereals.

The leaner meats are also relatively good sources of riboflavin and nicotinic acid, while in thiamin beef is relatively poor and pork is relatively rich.

On the other hand, meats contain relatively little of calcium, of vitamin A, or of vitamin C, so that in these respects they do not serve (as does a combination of milk and fruit) to make good the nutritional shortcomings of the breadstuffs and cereals.

Meat is a good source of phosphorus.

As to the relative availability of meat iron, the evidence is still conflicting.

All these general statements about meats refer chiefly to the muscle meats, since the glandular organs can, in the nature of the case, constitute but a small fraction of the general meat supply.

Eggs

We do not know the origin of the folk-lore verse to which Hutchison gave currency, characterizing eggs as:

Treasure houses wherein lie,
Locked by Nature's alchemy,
Flesh, and blood, and brain, and bone.

As rich sources of nutrients of which we do not always get enough, eggs well deserve inclusion among the "protective" foods. But they do not (like fruits, vegetables, and milk) tend to safeguard the hygiene of the intestine and the reserve alkalinity of the blood and tissues; and for these and other reasons students of nutrition tend to keep the egg in its place while giving a growing place to fruits, vegetables, and milk in the dietary.

Much of value might be learned from full-life, successive-generation experiments with dietaries containing different liberal allowances of eggs, fed to laboratory animals whose nutritional chemistry (in respect to the factors of which eggs are important sources) is similar to our own.

In some respects eggs may be regarded as standing midway between meat and milk in nutritional characteristics. Like meats, they have been considerably studied as to particular points; but still need more comprehensive investigation by feeding at different levels throughout entire life cycles of successive generations.

Both the recent food consumption studies by Stiebeling and Phipard (1939) and the earlier series of dietary studies already mentioned show that eggs occupy strikingly differ-

ent degrees of prominence in the dietary according to economic conditions.

Egg-protein resembles milk-protein in nutritional efficiency, and the egg is also a good source of phosphorus and of vitamins A and B, but practically negligible as a source of vitamin C. As a source of calcium eggs rank below milk and the green vegetables but above the meats, sweets, and bakery products.

Fruits and Vegetables

Fruits and vegetables vary greatly among themselves in their calorie and protein values; yet for some purposes it may be convenient to think of them as a group. There is no clear-cut line of subdivision between them and as a whole the fruits and vegetables are chiefly significant in the dietary as sources of mineral elements and vitamins. The relative richness in vitamin C of some of the fruits and vegetables,—conspicuously oranges, grapefruit, and tomatoes,—and the importance which we now attach to liberal dietary supplies of this vitamin, mean that fresh fruits and succulent vegetables generally (and citrus fruits particularly) have been rapidly and properly promoted from the status of an occasional luxury to that of a good daily investment in nutritional values.

Thus in the 224 dietaries above mentioned, less than 16 per cent of the total food expenditure was for fruits and vegetables; in return for which they furnished 12 per cent of the calories, 10.3 per cent of the protein, 17.4 per cent of the phosphorus, 18 per cent of the calcium, and 30 per cent of the iron. In that series vitamin values were not computed but the importance of the fruits and vegetables in this respect is indicated by the following. Stiebeling and Phipard (1939, page 86) show that in 26 East North Central families spending $1.88 to $2.49 weekly per capita for food in 1935, fruits and vegetables represented 19.9 per cent of the total food cost and furnished 14.1 per cent of the calories, 12.2 per cent of the protein, 15.7 per cent of the calcium, 20.0 per

cent of the phosphorus, 32.4 per cent of the iron, 57.7 per cent of the vitamin A value, 39.5 per cent of the thiamin, 91.6 per cent of the vitamin C (ascorbic acid), and 20.7 per cent of the riboflavin.

Even though the fruits and vegetables vary widely among themselves, it is a safe conclusion that in general the higher the proportion of fruits and vegetables in the dietary the better will be its mineral content and vitamin value. The relative importance of the different types of fruits and vegetables as sources of individual mineral elements and vitamins has been sufficiently discussed in preceding chapters so that it need not be dwelt upon here.

Fruits, Vegetables, and Milk (the latter including cheese and ice cream)

When fruits, vegetables, and milk (including cheese and ice cream) are grouped together, the data for the 26 families reported, as above explained, by Stiebeling and Phipard become as follows:

These foods represent 32.0 per cent of the food cost; and furnish 24.1 per cent of the calories, 29.6 per cent of the protein, 79.7 per cent of the calcium, 48.5 per cent of the phosphorus, 39.0 per cent of the iron, 70.8 per cent of the vitamin A value, 53.1 per cent of the thiamin, 96.9 per cent of the ascorbic acid (vitamin C), and 56.1 per cent of the riboflavin.

It is evident that the practical way to reap the individual, family, and community benefit of the newer knowledge of nutrition is to see that fruits, vegetables, and milk have a high place in the dietary or food supply.

Nuts

Nuts are perhaps deserving of a more serious place in the diet than we have yet learned to give them. They are rich in protein of good nutritive value, and in thiamin.

Peanut butter spread on white bread tends to restore the protein, vitamin, and some of the mineral values of the whole wheat grain which are rejected in the milling process.

The peanut, of course, is a legume comparable with peas, beans, and lentils. Most other nuts ("real" nuts as some fanciers say) are botanically fruits and agriculturally tree crops. The culture of nut trees and the consumption of nuts might well be increased.

Fats (including Fatty Oils)

The problem of the proper place of commercial fats in the food supply presents several complications.

For one thing, the demand for fat is (quantitatively speaking) largely a matter of national habit. During 1914-1918 when a concerted effort was being made to ensure adequate food supplies to all the Allied peoples, it was found that a much higher per capita supply of fat was needed for efficiency and morale in the Occidental than in the Oriental countries. For the civilians as well as the soldiers of the European peoples, it was deemed important to provide at least 70 grams of fat per capita per day, while the Oriental peoples felt no need of so much.

People of the Western World want liberal use of fats in cookery to give their foods the flavors, and perhaps even more particularly the textures, to which they have accustomed themselves; and also "fat sticks to the ribs" in the sense that a meal of a given calorie value does not so quickly leave the stomach if a liberal percentage of its calories is in the form of fat. And so, of course, the longer each meal stays in the stomach, the less likely is it that the muscular signals from an empty stomach ("the pangs of hunger") will be felt before the next meal. The problem of specifically essential fatty acids has been discussed in Chapter II.

Sugar and Other Commercial Sweets

In nature the sweetness of the nectar of a flower is quite clearly a bait to secure the visit of the bee and the distribution of the pollen by his agency. The sweetness of the flesh of a fruit guides animals to consume something that contains not only sugar but also significant amounts of mineral ele-

ments and vitamins; and in baiting the animal to eat the fruit it also serves the plant by securing distribution of its seeds.

The biological utility of artificially refined sugar is much more circumscribed. Nutritionally it is the extreme case of a one-sided food; for it furnishes calories and nothing else.

The repeated research findings of Bunting and others, that increasing prominence of sugar in the dietary means increasing proportion of tooth defects in children, should not be ignored.

It is probably true for the people as a whole, as was said in a discussion of the problem of sweets for children (published as a leaflet by the American Child Health Association and reprinted by the American Public Health Association in a report of its Committee on Nutritional Problems), "that in general the proper place of sugar in the food supplies and eating habits . . . is not in such concentrated forms as candy, nor in the indiscriminate and excessive sweetening of all kinds of foods, but rather as a preservative and flavor to facilitate the introduction into the . . . dietary of larger amounts of the fruit and the milk, the importance of which to . . . health has been increasingly emphasized with each year's progress in our knowledge of nutrition."

Within a relatively short time sugar consumption has grown as we saw in Chapter II from around 10 pounds to over 100 pounds per capita per year in the United States, so that now most families take over a tenth, and many take as much as a fifth, of their total food calories in the form of sugar which furnishes practically no protein, mineral element, or vitamin. Obviously this must have the nutritional result of lowering the intakes of protein and of the mineral elements and vitamins by one-tenth to one-fifth from the levels at which they would otherwise be consumed. Is this desirable?

EXERCISES

1. Answer the question with which the above text ends and explain your answer in from 500 to 1000 words.

2. Using such Governmental and sugar trade statistics as are available at the time of your writing, show whether there has been a significant increase or decrease in American per capita consumption of sugar since 1920-25.

3. How do recent advances of knowledge of the differences between the merely adequate and the optimal levels of intake affect your judgment as to the use of so much "refined" food as was common in the first third of the twentieth century?

4. Discuss recent trends toward the use (1) of a larger proportion of the wheat grain (or an admixture of whole-wheat with white flour) in bread making; (2) of fortification of white flour with wheat germ or with mineral or vitamin concentrates; (3) of an increased proportion of milk (whole or skimmed, fresh or canned or dried) in breadmaking; (4) of yeasts especially developed for their high thiamin content.

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Chapter XX

FOOD COSTS AND VALUES: NUTRITIONAL GUIDANCE IN FOOD ECONOMICS

Introductory

As Lord Astor put it in his discussion of the League of Nations' Mixed Commission's report, described below, the newer scientific knowledge of nutrition makes the practical problem of food supply a question not only of enough food, but enough of the *right kinds* of food.

And as we saw in Chapter I, individual, family, and community food supplies doubtless have been and still are responsible for many of the relatively low levels of accomplishment for which in lack of this new knowledge an undue share of blame has been laid upon heredity. Our Federal Secretary of Agriculture, primarily a geneticist, and more recently a student of nutrition also, is quite explicit in applying the new view to our own population and food habits.

In his Foreword to the 1939 Yearbook of the United States Department of Agriculture, Secretary Wallace has written that probably 99 per cent of the people born in this country have heredity good enough to enable them to become productive workers and excellent citizens, but that half of them "do not get enough in the way of dairy products, fruits, and vegetables to enable them" to enjoy the full measure of health and vigor which is potential in their hereditary birthright. And the reasons are largely, though not wholly, economic.

In the choice of one's food, or in purchasing the food for a family or other group, one usually must observe an economic limitation. This fact has been implicitly recognized in the foregoing chapters and accompanying Exercises, while the present chapter undertakes a somewhat more explicit approach. Also, whereas previous chapters have been written primarily in terms of the individual, this one is in terms of the family food budget: partly because the majority of readers will presumably spend most of their lives as members of such groups; and partly because in studies and writings on food economics the family is usually considered as the consumer. To comply with the custom of the literature of the subject in this respect involves no failure of appreciation of the fact that in another aspect the food as it enters the home is still a "raw material" for processing by the homemaker.

The Economic Setting of the Problem of Better Nutrition

According to what seem to be the generally accepted estimates, nearly two-thirds of the families in the United States have incomes of less than $1500 *per family* per year; about one-fourth have between $1500 and $3000; and less than one-tenth have over $3000 per family per year.

Detailed advice upon the budgeting of incomes would lead beyond the scope of this book. Such problems are treated fully and from broad viewpoints in Andrews' *Economics of the Household* (Second Edition, 1935) and Rose's *Feeding the Family* (Fourth Edition, 1940).

It is, however, part of the function of this chapter to emphasize the fundamentally important fact that science now finds it possible to do more for health, efficiency, and welfare through nutrition than was previously supposed or even seriously imagined; so that, with nutrition carrying a larger share of the responsibility for making life worth while, it is logical that an increased share of the cost of living should be budgeted for the cost of food.

And, even under present economic conditions, it is possible for this to be done.

Stiebeling and Phipard (1939)*, whose findings furnish one of the major bases for much of the present-day study of the problems with which this chapter deals, report that the *food expenditures per person per week* by the *middle half of the city families studied in each region*, December 1934 to February 1937, were as in Table 19:

TABLE 19.—FOOD EXPENDITURES OF TYPICAL FAMILIES

	PER PERSON PER WEEK
WHITE FAMILIES	
North Atlantic	$2.15–$3.50
East North Central	2.10– 3.35
West North Central	2.20– 3.60
South Atlantic	2.00– 3.10
East South Central	1.60– 2.75
West South Central	1.85– 3.00
Mountain	2.00– 3.00
Pacific	2.25– 3.60
NEGRO FAMILIES	
Middle Atlantic	1.75– 3.65
South	1.05– 2.15

Statistics of expenditure of the income of the people show that such lines of expenditure as adornment (other than clothing) and amusement (other than by means of food, clothing, housing, and the automobile) run to very significant proportions of even the lower incomes.

Thus the improvement of food economics under the guidance of nutrition may be two-fold: (1) a better distribution of the food money; and (2) often also the allotment to food of a somewhat higher proportion of the total income, or of the total budget for the cost of living. And such a suggestion is *not* a proposal to diminish the few pleasures of the poor; rather, it helps them to gain their greatest pleasures.

For the satisfaction derived from such higher accomplish-

*Full reference among Suggested Readings at the end of the chapter.

ment as is made possible by higher health and efficiency exceeds the pleasure of mere consumption of goods; and in most families it is in turn exceeded by the contemplation of still higher health, efficiency, and accomplishment in and by the children who get the benefit of the newer knowledge of nutrition more completely and from an earlier age.

Whatever the income, then, much depends upon the individual consumer's choice and use of food.

Only the general principles of the choice of food as guided by nutritional knowledge, and of the use of such knowledge in the allotment of the food money to the different types of food, can be discussed here. For the full development of the subject with calculations and actual meal plans for different types of people and for family groups, see Rose's *Feeding the Family* and *Laboratory Handbook for Dietetics*.

Food Budgets as Guided by Nutritional Knowledge

It may be helpful at this point to summarize very briefly, and in a somewhat different sequence, the nutritional characteristics of the chief types of foods as studied in Chapter XIX.

Most of the common articles and types of food may be grouped according to their chiefly significant nutritional characteristics as follows:

(1) *Breadstuffs and other grain products*.—Economical sources of energy and protein but not satisfactory in their calcium content or in most of the vitamin values.

(2) *Sugars and fats*.—Chiefly significant from the nutritional standpoint as supplementary sources of energy, although some fats are also important as sources of fat-soluble vitamins. (The small amount of fat as such, particularly of certain unsaturated fatty acids, which now appears to be specifically needed in nutrition is doubtless amply furnished by the milk, fruits, and vegetables of a normal food supply.)

(3) *Meats (including fish and poultry)*.—Rich in protein or fat or both, but showing, in general, about the same

calcium and vitamin deficiencies as do the grains, though lean meats are relatively richer in riboflavin.

(4) *Fruits and vegetables.*—Greatly variable in their protein and energy values, but highly important as sources of mineral elements and vitamins.

(5) *Milk.*—Important as source of energy, protein, mineral elements, and vitamins. The most efficient of all foods in making good the deficiencies of grain products and in ensuring the all-round adequacy of the diet.

(6) *Eggs.*—As these occupy a less prominent place in the usual food budget, they are sometimes included in a group with meats, but nutritionally it is more satisfactory to group eggs by themselves. In some respects they resemble meat, in other respects they resemble milk, and in still other respects they have somewhat distinctive properties.

From the results of numerous studies made by the United States Bureau of Labor Statistics, by the United States Department of Agriculture, and by the New York Association for Improving the Condition of the Poor, it can be estimated that of the total expenditure for food by the typical American family, from 25 to 40 per cent is for meats and fish (including poultry and shellfish); about 5 per cent for eggs; about 10 per cent for milk, cream, and cheese; about 10 per cent for butter and other fats; from 15 to 20 per cent for bread and other cereal and bakery products; about 5 per cent for sugar and other sweets; about 15 per cent for fruits and vegetables; and about 5 per cent for miscellaneous foods and food adjuncts. At the same time it is plain that such a food budget, however prevalent, need not be regarded as fixed.

For purposes of more detailed analysis and planning, a classification of foods into twelve groups or types is now being used to a considerable extent, especially in government publications. This plan is described and illustrated in Appendix F (at the back of this book) which may well be studied at this point by those desiring such fuller consideration of diet planning.

Just what prominence should be given to each type of food in the dietary of a given individual or family, or in a community or national food supply, is a problem calling for consideration of many factors. One important feature of the problem is to ascertain how the normal variations in the distribution of expenditure among the various types of food materials affect the relative proportions of nutrients in the resulting mixed diet. The data of Table 20 permit a comparison between the expenditures for the different types of food and the returns from each in terms of energy, protein, calcium, phosphorus, and iron in the case of the American dietaries mentioned above. In individual dietaries the returns will naturally vary according as an economical or an expensive food of its kind is chosen, but in the average of 224 different dietaries, the danger of error due to such individual variations is minimized. This table will now be discussed briefly in the light of the more recent data of Stiebeling as shown in Table 17, Chapter XIII, and of Stiebeling and Phipard (1939).

TABLE 20.—AVERAGE PERCENTAGE DISTRIBUTION OF COST AND NUTRIENTS IN 224 AMERICAN DIETARIES

TYPE OF FOOD	RELATIVE COST	CALORIES	PROTEIN	PHOSPHORUS	CALCIUM	IRON
Meat and fish..	32.19	18.99	35.34	26.36	3.86	30.37
Eggs..........	5.47	1.77	4.64	4.02	3.64	6.25
Milk and cheese	10.59	8.08	11.56	20.61	55.76	5.11
Butter and other fats...	9.55	10.32	0.31	0.32	0.73	0.33
Grain products	18.29	38.20	37.25	30.27	15.67	25.87
Sugar and molasses.....	4.57	10.06	0.14	0.20	1.81	1.80
Vegetables.....	10.55	9.05	9.55	15.58	14.87	26.42
Fruit.........	5.31	2.99	0.78	1.82	3.15	3.29
Nuts..........	0.15	0.14	0.11	0.13	0.07	0.09
Food adjuncts.	3.33	0.40	0.32	0.69	0.44	0.47

The average food value per man per day of the dietaries summarized in Table 20 was calculated as follows:

Energy	3256.	Calories
Protein	106.	Grams
Phosphorus	1.63	Grams
Calcium	0.74	Gram
Iron	0.0179	Gram

Comparing these averages with the amounts actually required for normal nutrition (as summarized in previous chapters) it will be seen that the freely chosen dietaries contained in the average a more liberal surplus of protein, phosphorus, and iron than of calories or of calcium. Correspondingly, we find that the number of individual family dietaries deficient in calcium and in total food value (calories) is high enough to cause serious concern, while the cases of deficiency of phosphorus or iron were considerably less frequent and there were few if any cases showing an actual deficiency of protein.

If we study the margin by which the average intake exceeds the actual requirement, we can hardly avoid the conclusion that the insurance carried by average American food habits, though slowly changing under the guidance of nutritional knowledge, is not yet entirely consistent as between the different factors of nutritional need. This consideration now takes on added importance in view of the recent findings that for *best* results the intakes of calcium, riboflavin, and of vitamin A, probably also of vitamin C, and possibly of thiamin should be much higher than the minimal-adequate or demonstrably needed amounts.

Stiebeling and Phipard (1939, page 99) find in the data of representative family food consumption in 1934-37, as had been found in earlier studies, that about one-sixth of the people get dietaries of calcium content below that which laboratory studies indicate as a minimum for fully normal nutrition.

The problem of "dietary standards" has thus been rendered even more difficult than it was before by the recent

discovery, *for some nutrients but not for others*, of unexpectedly wide zones of desirable margin above the needs of minimal adequacy. It is, however, probably safe to say that (while other deficiencies may be more frequent in certain limited regions) in the food supplies of the people throughout the United States generally, the point at which enrichment is most needed is in the calcium content. And this enrichment should be accomplished by increasing the proportions of milk, or green vegetables,* or both, in the dietary, for these bring other nutritional advantages along with the calcium.

It was because these two types of food, milk and green leaf vegetables, are rich both in calcium and in vitamin A value that McCollum has given them such special emphasis, believing that calcium and vitamin A are the nutrients which we are most apt to receive in suboptimal amounts from our ordinary dietaries. In the light of Stiebeling's and Phipard's findings, and of the laboratory research which has shown such wide zones between the merely adequate and the optimal in both these cases, there is still strong reason for such food selection as to enrich the dietary in calcium content and vitamin A value. Riboflavin certainly, and vitamin C probably, also have similar wide zones of beneficial increase above the level of minimal adequacy, as we have seen in Chapters XI and XIII.

Thus there are now several strong nutritional reasons for so managing the food budget as to give fruits, vegetables, and milk (including, if desired, cheese, cream, and ice cream) a larger place in the dietary than has been customary hitherto.

Based apparently upon a recommendation originally made by Gillett, the following simple food budget for city families has been widely quoted and found useful:

*Other than spinach, New Zealand spinach, chard, and beet greens, whose oxalic acid makes their calcium useless.

Divide your food money into fifths—
- One fifth, more or less, for vegetables and fruit;
- One fifth, or more, for milk and cheese;
- One fifth, or less, for meats, fish, and eggs;
- One fifth, or more, for bread and cereals;
- One fifth, or less, for fats, sugar, and other groceries and food adjuncts.

The recommendation that a fifth or more of the total food money be spent for bread and cereals aims at making a dietary more economical than the American average. In practice, the proportion spent for bread and cereals may (and usually does) vary with the need for strict economy. It must usually be high in an extremely low-cost dietary and may be considerably lower where the level of expenditure is more liberal.

Whatever the level of expenditure, however, it seems wise to observe the two suggestions that:

(1) at least as much should be spent for milk (including cream and cheese if used) as for meats, poultry, and fish; and

(2) at least as much should be spent for fruits and vegetables as for meats, poultry, and fish.

These latter suggestions seem to have been found useful as a guide in both low-cost and liberal-cost food budgets and can obviously be applied in all cases in which even the simplest of records of expenditures are kept. They tend to make milk, vegetables, and fruits more prominent than in the average American dietary of the present or of the recent past.

From among the dietary records above discussed, 25 were taken at random and a calculation was made to see how their nutritive values would have been affected if, with no change in the amount of money spent or in the kinds of foods selected, the quantities of the different food groups had been simply readjusted in accordance with the two suggestions just given. It was found that such readjustment

would leave the protein practically unchanged in amount while the calories and iron would be slightly increased and the calcium and phosphorus materially increased and brought into better quantitative relations with each other. Furthermore, the dietaries thus adjusted would undoubtedly be improved in their vitamin A and C values.

That progress in this direction is already taking place, gradually but upon a large scale, is shown both by the United States Department of Agriculture's statistics of production, consumption, and railway transportation of different types of food, and by such studies of urban food habits as those conducted by the New York Association for Improving the Condition of the Poor and summarized by Gillett and Rice (1931) in the publication cited among the references at the end of this chapter.

The term *protective foods* was coined by McCollum and (as noted above) first applied only to milk and the green leaf vegetables, as being the two types of food rich in both the two factors, calcium and vitamin A value, which he had come to regard as most often deficient in the dietaries of American and European peoples.

The research findings of recent years have extended this conception in two ways. We have come to realize that enrichment of the dietary in vitamin C and riboflavin, as well as in vitamin A and calcium, is usually beneficial; and this not merely for protection against actual deficiency, but also for the promotion or enhancement of vitality,—of "positive," or "buoyant," or better-than-average, health. Thus the idea has, perhaps, already outgrown the literal meaning of the word "protective"; but the term continues to do service with an enlarged and more constructive significance.

In this sense, and with the objective broadened to include the enrichment of the diet in the four factors,—calcium, riboflavin, and vitamins A and C,—we now apply the term protective foods to fruit, vegetables, and milk, with or

without eggs.* Milk furnishes all four of the chemical factors just mentioned and is an outstanding source of three of them; while each of the other three types of food just mentioned is regarded as a good source of some two of the four factors. The richness of eggs in vitamin A and riboflavin fully entitles them to admission to this category according to this latter criterion, and the vitamin D and iron content of eggs and the high nutritive value of their proteins are all nutritional assets, especially for the growing child; but eggs do not, like the other protective foods, have the property of reducing intestinal putrefaction and promoting the development of a wholesome bacterial flora in the digestive tract. For this and some other reasons eggs are more cautiously emphasized, while of milk, fruit, and vegetables we now believe that (within reason) the larger the proportion of the needed calories taken in these three forms the better.

There has for some years been a steady and well-justified trend toward higher nutritional appreciation of the fruits and vegetables; and this trend still continues. Hence it is an expression of the consensus of nutritional findings and opinion (and not merely, though also, of the judgment of the present writers) that we recommend for fruits and vegetables a still greater prominence in the dietary (or food budget) than is found in most previous books and bulletins.

Stiebeling's studies of food consumption at different economic levels show that as purchasing power rises from levels of severe poverty to those permitting a little more freedom in the choice of food, there is at first an increase in fruit and vegetable consumption fully proportionate to the increased per capita expenditure for food. But with still more comfortable levels of expenditure the extra food money does not go as largely to increased consumption of fruits and of succulent vegetables as would be desirable. In other

*A widening of the term "protective foods" to include meat also has been proposed; but at the time of writing (1940) it is too early to judge whether this redefinition of the term will come into general use or not. Whole grain cereal products have also been "nominated" for inclusion in the "protective" group of foods.

words the consumer demand represented by the nation-wide data of about 1933-36 is responsive to, but not yet fully abreast of, the guidance of the newer knowledge. Consumers still are too apt to think that about two pounds a day of fruits and vegetables is as much as they are justified in eating, whereas our present nutritional viewpoint is that certainly a third pound of per capita consumption of total fruits and vegetables (and very probably more) is an excellent investment.

Prominence of milk, fruits, and vegetables in the dietary ensures liberal intakes of calcium, riboflavin, nicotinic acid, and vitamins A and C; and, perhaps, in somewhat less prominent but still important degree, of phosphorus, iron, and thiamin.

Whole grain cereals in adequate proportions provide abundance of thiamin, iron, manganese, copper, and supplementary phosphorus. There has been some discussion as to the availability of the cereal phosphorus, but actual feeding experiments leave no doubt that we assimilate more phosphorus from whole wheat than from white bread. Good availability of the thiamin and of the iron of whole wheat is clearly established.

Stiebeling and Phipard (1939), in the general summary of their findings from the study of about 4000 family food-consumption records representing 43 cities or towns in eight major geographical regions of the United States during the period December 1934 to February 1937, point out that the *average* dietaries of this period (while already showing some effects of the teachings of the newer knowledge of nutrition) included only one-half to two-thirds as much milk and less than two-thirds as much of fruits and vegetables as did the dietaries which they graded as good, and add: "But even these *good* diets fell short of the allowances of these protective foods believed by many authorities to be optimal."

Most of these 4000 families spent between 25 and 40 per cent of their income for food. On the average, those having

more money to spend for food increased their purchases of milk, butter, cream, eggs, meat, fruits, and succulent vegetables in greater degree than their purchases of grain products, sugars, and fats other than butter. Thus when total food expenditure was 200 per cent higher, that for fruits was 200 to 400 per cent higher but that for grain products and fats other than butter was only about 30 to 35 per cent higher.

Thus the newer knowledge of nutrition does not suggest any serious departure from the natural inclinations of present-day American consumers: rather it offers guidance and "implementation" for the realization of the fullest measure of satisfaction from a movement in the direction in which most consumers already wanted to go.

But for even a reasonable approach to best results the teaching of greater prominence of fruits, vegetables, and milk (including cheese, cream, and ice cream) in our dietaries and food supplies should be emphasized and practiced in higher degree than at present.

Stiebeling and Phipard find that in every region studied families spending only small amounts of money for food use only small quantities of milk. And in the average of all the white families studied, while one-fourth to one-third of the food money was spent for meat, fish, poultry, and eggs, only one-fifth to one-fourth was spent for fruits and vegetables, and only one-eighth to one-sixth for milk and cheese. (The negro family food budgets showed still less appreciation of fruits, vegetables, and milk.)

Progress in the direction of giving higher place in the dietary to fruits, vegetables, and milk is (up until 1940, at any rate) more evident in the feeding of children than of grown people.

Dr. Mary S. Rose permits us to extract the data of Table 21 from her current teaching of "working plans for the construction of adequate diets."

TABLE 21.—ROSE'S RECOMMENDATIONS ADAPTED

	PERCENTAGE OF TOTAL CALORIES FROM FRUITS, VEGETABLES, AND MILK
For Children	
1– 2 years	70–85
2– 3 "	65–72
3– 4 "	62–69
4– 5 "	59–68
6– 7 "	54–60
8– 9 "	53–58
10–12 "	51–56
For High-School Boys and Girls	
at 2000 Calories	48–53
" 2500 "	42–45
For Healthy Adults on Low to Moderate Incomes	28–30
For a Family of 2 Adults and 3 Young Children on Low to Moderate Income	37–42

Table 22 shows the "distribution standards" for children's dietaries recommended by Dr. Rose and Table 23 a differentiation according to economic level.

TABLE 22.—DISTRIBUTION OF CALORIES IN DIETS OF CHILDREN OF 4 TO 12 YEARS

AGE IN YEARS	PER CENT OF TOTAL CALORIES FROM EACH CLASS OF FOOD					
	Foods from Cereal Grains	Milk	Vegetables and Fruits	Fats[a]	Sugars and Sweets	Eggs, Cheese, Meat, and Other Flesh Foods
4–5	23–25	45–50	14–18	5–8	2–5	5–6
5–6	23–25	45–50	14–18	5–8	2–5	5–6
6–7	20–25	40–45	14–15	10–12	3–4	4–5
8–9	20–25	38–42	15–16	12–13	4–6	5–6
10–12	20–25	34–38	17–18	13–14	6–8	7–8

[a]At least part of the fat to be butter or something known to furnish its equivalent of vitamin A.

Table 23 shows corresponding distribution standards to guide the planning of minimum cost and moderate cost dietaries, respectively, for children of ages 5 to 16 years. The minimum-cost standard is based on the recommendations of the Committee on Economic Standards of the

New York Nutrition Council. The moderate-cost standards are those used by Rose and Gray in judging the dietaries of child-caring institutions.

TABLE 23.—DISTRIBUTION OF CALORIES IN DIETS OF MINIMUM AND OF MODERATE COST FOR CHILDREN OF AGES 5 TO 16 YEARS

Food Group	Minimum-Cost Diet	Moderate-Cost Diet
	Per Cent of Total Calories	*Per Cent of Total Calories*
I. Foods from cereal grains	37	24
II. Milk	22	32
III. Vegetables and fruits		
A. Dried legumes	3	1
B. Other vegetables and fruits	13	16
IV. Fats and oils	14	12
V. Sugars and sweets	5	7
VI. Meat, eggs, cheese	6	8

For family groups Stiebeling's "dietaries at four levels of cost" and supplementary suggestions will afford much additional guidance. An independent discussion based essentially upon them has also been published by Hambidge. (See suggested readings at the end of the chapter.)

Omitting the emergency diet, Stiebeling and Ward's recommendations were as shown in Table 24.

It is of interest to compare some other recommendations with those of Stiebeling and Ward as summarized in Table 24.

McCollum's recommendation for milk consumption is one quart per capita per day. Inasmuch as new research findings, since 1933 when the recommendations of Stiebeling and Ward were published, tend strongly to raise the probable optimal intake of calcium and riboflavin, we believe that this constitutes a sound reason for preferring 365 quarts rather than 305 quarts of milk per capita per year.

Also we believe that the trend of advance of nutritional knowledge since 1933 makes it logical to give an even more

TABLE 24.—YEARLY PER CAPITA CONSUMPTION OF FOODS AT DIFFERENT ECONOMIC LEVELS AS RECOMMENDED BY STIEBELING AND WARD

Food		Adequate Diet at Minimum Cost	Adequate Diet at Moderate Cost	Liberal Diet
Milk[a]	*quarts*	260	305	305
Potatoes, sweetpotatoes	*lbs.*	165	165	155
Dried beans, peas, nuts	"	30	20	7
Tomatoes, citrus fruits	"	50	90	110
Leafy, green, and yellow vegetables	"	80	100	135
Dried fruits	"	20	25	20
Other fruits and vegetables	"	85	210	325
Flour, cereals	"	224	160	100
Fats[b]	"	49	52	52
Sugars	"	35	60	60
Meats, poultry, fish	"	60	100	165
Eggs	*dozens*	15	15	30

[a]Including such milk products as share its essential nutritional characteristics. The approximate equivalents are, as given by the U. S. Dept. Agriculture, for 1 quart of fluid whole milk: 17 ounces of evaporated milk; 1 quart of fluid skim milk and 1.5 ounces of butter; 5 ounces of American Cheddar cheese; 4.5 ounces of dried whole milk; 3.5 ounces of dried skim milk and 1.5 ounces of butter.

[b]In the data of this table, bacon and fat pork are included under Fats and not under Meats.

prominent place to fruits and vegetables in the dietary than is given in the Stiebeling and Ward recommendations.

We may repeat here the recommendation: (1) that at least half the total calories be taken in the form of fruit, vegetables, and milk (including cheese, cream, and ice cream); and (2) that at least half the cereals and breadstuffs consumed be in approximately whole-grain forms.

Abundance of intake of thiamin is ensured by the use of *foods not too largely denatured by refining;* while abundance of vitamins A and C, and of calcium, depends chiefly upon the *kind* of food selected. In other words thiamin is distributed in relative abundance in a wide variety of plant and animal tissues, while vitamins A and C are not so widely distributed in generous concentrations, but occur importantly in particular foods: vitamin A in green and yellow vegetables, milk (and all of its products which

contain its fat), and in egg yolks; vitamin C particularly in citrus fruits and tomatoes, and significantly in a number of other fresh fruits and succulent vegetables.

EXERCISES

1. Taking the data of Table 20 as fairly typical of such American dietaries as are only beginning to be influenced by the newer knowledge of nutrition, what changes in the distribution of the food money among the different types of food would you now recommend?

2. If the allotment of the food money were readjusted so that as much was spent for milk and cheese, and also as much for fruits and vegetables, as for meats and fish, would you anticipate an increase or a decrease: (*a*) in the calcium content of the dietary; (*b*) in its ascorbic acid (vitamin C) content; (*c*) in its thiamin (vitamin B_1) content; (*d*) in its riboflavin content; (*e*) in its vitamin A value; (*f*) in the excellence of its nutritional character as a whole?

3. As it is known that meat and fruit do quite directly "compete for the consumer's food money," what effect would you anticipate from the shifting (*a*) of one-third of the customary expenditure for meat and fish to fruit instead, (*b*) of one-third of the customary expenditure for fruit to meat instead?

4. Assuming such readjustment of the food budget as you under the guidance of the newer knowledge of nutrition consider it wise to make, would this call for any essential change in the set-up of menus or meal plans, or only for increases or decreases in the sizes of servings of certain foods?

5. Make meal plans set up in the general style used in Rose's *Feeding the Family* and incorporating in full your own judgment as to the best relative amounts of the different types of food.

6. Compare your individual dietary or food consumption record, or that of a family whom you know, with the "Kinds and quantities of food for a year" proposed by the table in Appendix F, taking the data on such line or lines in that table as most nearly correspond with your case or that of the family whose dietary or food record you are comparing.

Does your dietary omit any one of the twelve "kinds" into which foods are grouped in that table? If so, is the omission an advantage or a disadvantage nutritionally? Why?

Which of the twelve kinds of foods are more prominent in your dietary than in the "low-cost good diet" proposed by the United States Department of Agriculture as quoted in Appendix F?

In each of these cases, is the greater prominence of this kind of food in your dietary advantageous or disadvantageous nutritionally? And how does it affect the cost of your dietary?

7. Having in mind the fact that recent and current research shows some foods to be better investments than we have hitherto known, could you now improve your dietary nutritionally without seriously increasing its cost?

How much money per year could be made available for the further improvement of your dietary (or that of the family you have in mind) by a partial shifting of expenditure from less important items of the cost of living?

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Chapter XXI

HOW TO MAKE NUTRITIONAL KNOWLEDGE MORE EFFECTIVE

("NUTRITION POLICY": PUBLIC AND PERSONAL)

One thing that is needed in order to make nutritional knowledge more effective is a keener realization, a more constant consciousness, of the fact that there is a highly significant difference between the merely adequate and the optimal in nutrition. To bring about this realization is not a hopeless task, for progress has been made already. Witness the evidence of growing appreciation of fruits, vegetables, and milk as shown both by comparative dietary studies at a 15-year interval in New York City and by the Federal marketing statistics; and witness also the editorial statement in the *Journal of the American Medical Association* that the difference between merely passable health and buoyant health is coming to be more appreciated.

Farmers know that they cannot afford to keep animals of merely passable health. The production that makes a farm animal profitable is dependent upon a state of nutrition more nearly optimal than that which is merely adequate to pass a veterinary inspection. Gove Hambidge remarks that many a man would be "ashamed to feed his livestock as casually as he feeds his family"; and suggests that it would be no more than intelligent for us (with the food-production possibilities which our country affords) to build a nation of people as sturdy "as the animals in a good barnyard."

To change the comparison, would one expect the best results in athletics from a group of students whose minimal-adequate nutrition put them only just over the line between being on sick-list and being of "passable" health from the viewpoint of medical inspection? Doesn't every athletic coach as a matter of course select his material from among those whose nutritional condition is such as to support "positive" or "buoyant" health?

The preceding paragraphs do *not* imply that nutrition is *solely* responsible for the difference between merely passable health on the one hand and positive or buoyant health on the other. Physical training plays a large part in the production of successful athletes; and heredity is a large factor in superiority both in the human family and among its domestic animals. The point is that both heredity and training become more productive when supported by the superior nutritional condition and internal environment to which our newer knowledge can serve as a guide; and that more can now be accomplished through nutrition than we have previously been accustomed to suppose.

In the exceedingly modest terms in which Sir Frederick Gowland Hopkins put it, "Nurture can assist Nature to a larger extent than Science has hitherto thought."

Thus a very important first step in making nutritional knowledge more effective is to train oneself, and to help others, to an adequate realization of its potentiality.

Nutrition Policy is Made Effective by both Economic and Educational Methods

How each of us may use nutritional knowledge as effectively as possible in our own lives, and extend its benefits to the lives of as many others as possible, is both an economic and an educational problem.

It is economic in the sense that most of us would follow the guidance of the newer knowledge of nutrition somewhat more readily, fully, and effectively if we had more money to spend for food; and in the sense of the wider view which

shows that malnutrition is enormously more prevalent among the poor than among the well-to-do. As incomes rise above the poverty level, nutritional conditions automatically improve. With more money to spend for food, people in general buy themselves nutritionally better food supplies than those to which the majority now feel themselves confined by the limitations of their purchasing power.

Yet at the same time, it is also an educational problem; for careful studies show clearly, as has recently been especially emphasized by Steibeling, that a very large proportion of families can have nutritionally much better dietaries than they now do, even at their present levels of expenditure for food.

Recognizing that both economic and educational problems are involved, many people are now of the opinion that the primary and fundamental need is *nutritional consciousness* or *nutrition policy*; and that when a right policy in regard to nutrition is consciously adopted, both educational and more directly economic methods will be found or made effective for its promotion.

One of the earliest and most clear-cut examples of a government acting on nutrition policy was when a Baltic State lowered its tariff duty upon imported fruit with the officially declared purpose of increasing the consumption of fruit by its people, in the interest of higher health through enhanced nutritional wellbeing.

At about the same time Great Britain gave worldwide circulation to an official (Downing Street) state paper entitled "Nutrition Policy," and began a movement for bringing the benefits of the newer knowledge of nutrition to its home population which was characterized in the *Atlantic* of February 1936 as "staggering in its utilitarianism." The London *Times* "editorially, reading like a social-service organ," supported the proposition that milk must not be used for making butter so long as British families go short of the fresh milk they should have. Among other

measures, the government gave employment for the raising of increased amounts of those foods which, under the guidance of the newer knowledge, were held to bring most benefit to the consuming public; and established marketing boards, operated at government expense, to ensure for such foods as milk, eggs, fruits, and vegetables, the lowest possible price to consumers with an adequate return to the producers. Special provision was also made that a school-lunch of milk be given to all school children: at cost, or for what they can pay, and at public expense to those who can pay nothing. The comprehensive nutrition policy of which this is but an indication is the result of such experiences as the high proportion of young men rejected as physically unfit for army service, the fact that a large proportion of those rejected on physical examination passed the same examination after having been properly fed for six months, and the fact that a dietary "which had been planned with the best of intentions for the welfare of the boys who were to receive it" still required a more liberal allowance of milk to enable the boys to make "the physical and mental development of which they were capable" (Corry Mann's experiment, previously mentioned).

It was especially to consider the broad aspects of nutrition policy that the League of Nations, under the challenge of the Delegate from Australia that something be done to "Marry agriculture and health," appointed a Mixed Committee representing nutrition, agriculture, and economics, under the chairmanship of Lord Astor, whose (above mentioned) declaration that, "It isn't sufficient that there be enough food; there must be enough of the *right kinds* of food," did much to give worldwide currency to this fundamental fact.

Manifestations of what may be considered a trend toward nutrition policy, even if fragmentary as yet, and suggestions for systematizing such policies, are collected and discussed in the "Final Report of the Mixed Committee of the League

of Nations on The Relation of Nutrition to Health, Agriculture, and Economic Policy" (Geneva, 1937).*

The British Medical Association took the initiative in organizing a conference on nutrition policy for Great Britain, which met in London, for the consideration of the wider aspects of nutrition, on April 27-29, 1939. Its keynote recommendation was as follows: "The conference called by the British Medical Association and composed of representatives of medicine, agriculture at home and overseas, industry, and education, is deeply impressed with the importance of nutrition to the national welfare. It urges upon the Government the formulation of a long-term food policy in which the requirements of health, agriculture, and industry shall be considered in mutual relation. It is convinced that measures to secure the more ready availability to all sections of the community of foodstuffs which are held to be desirable on nutritional grounds should be accompanied by an educational campaign to encourage their increased consumption."

In the United States the Federal and State Governments have made many contributions to nutritional research and education, but as yet have taken only tentative steps in the way of direct economic action to increase the proportion of the "protective" foods in the nation's food supply.

The allotment of the funds for soil conservation and the purchase of food for relief distribution under the surplus commodities law, are reported to have given some consideration to the nutritional evidence as to which foods should especially be increased in our national dietary. Presumably more will be done in this direction when a sufficient demand for it comes from the people as "nutrition conscious" consumers.

The various "food stamp" plans which are being tried as this is written (1940) might well incorporate a more explicit recognition of the principle that in filling any need for

*Printed in English and distributed in the United States of America by the Columbia University Press, New York City.

food, there should be insurance that the food which the consumer gets is of the kind, or of one of the kinds, which today's knowledge of nutrition emphasizes as especially desirable for increased consumption. It is important that the people needing public help with their food supply should be helped to get not only more food but more of the foods which will do most for their health and efficiency. It is also important that any public action in the way of increasing the market for food crops should encourage those crops whose sustained or increased production is most clearly to the advantage of the health interests of the people. If, as seems probable, progress is to come mainly through consumer demand, the sooner we realize this fact the sooner will nutritional knowledge become more widely effective for the general good.

The Red Cross also has done much for public education in nutrition, as notably by the work of its headquarters nutrition-educationalists, and by its loan of an able nutritionist to the New York City Department of Health until the budget of the latter could be made to provide for the nutritional service thus built up.

Underlying all these and many other activities for the extension of nutritional knowledge is, of course, the regular teaching of nutrition in schools and colleges, and the extension of such teaching into social welfare agencies of many kinds and into the technical training for the medical, nursing, and public health professions.

The fact that better nutrition of the people is both an economic and an educational problem is abundantly shown in the findings of Stiebeling and Phipard (1939).* When, having estimated individually the nutrient contents of a very large number of family dietaries, they grouped them as nutritionally "good," "fair," or "poor," it became quite clear (as indicated earlier in the chapter) that in general more money spent for food means a larger proportion of good dietaries; but also that with the same amount spent

*Full reference among Suggested Readings, Chapter XX.

for food some families get nutritionally good dietaries while some of their neighbors do not. For example, among East South Central city families with an expenditure of $2.50 a person a week for food, 32 per cent bought diets nutritionally "good," 31 per cent bought diets nutritionally "fair," and 37 per cent (at the same level of expenditure!) bought diets nutritionally "poor."

To a greater extent than in most economic and hygienic reforms, improvement in nutrition must be attained by the educational building up of new habits of conscious choice in the individual citizen, the cumulative effect of which is recognized as "consumer demand."

Thus the purchase of a dozen oranges or an extra quart of milk may confidently be expected to have a two-fold influence: (1) in the building of a higher level of nutritional wellbeing and resultant health and efficiency in the family or individual consumer; and (2) in the upbuilding of the agricultural industries which produce these articles of food.

Our everyday choices of food are probably among the most frequent and certainly among the most influential of the conscious choices that we make.

What serves us best is to accept wholeheartedly the guidance of the newer knowledge of nutrition, and to make a steady habit of acting upon this scientific guidance just as fully and regularly as circumstances permit. If to give to "the protective foods" that place in the dietary which present nutritional knowledge shows desirable involves turning over a new leaf in one's daily food practice, then let it be turned once for all: not grudgingly and hesitantly, not in a spirit of fussiness; but definitely and with cheerful thanks that science has shown us a way in which choices that we make every day can have unexpectedly far-reaching beneficial effects.

The phrase "protective foods" as here used means, as explained in a previous chapter, fruits, vegetables, and milk (including cheese, cream, and ice cream), with or without eggs. It leaves wide latitude for individual preferences and

for due consideration of economic conditions in the choice among fruits and vegetables; and also for choice among the different forms of milk (fresh, canned, and dried) and such of its products as sufficiently possess its nutritional characteristics,—fermented milk, cheese, cream, and ice cream.

As explained in a previous chapter, we interpret findings now available as indicating that for the best results as much as half of the needed food calories should be taken in the form of fruit, vegetables, and milk in some form or forms. For those who do not find it feasible to plan their food in terms of calories, much the same result will usually be obtained if at least half the expenditure for food is for fruits, vegetables, milk, cheese, cream, and ice cream. To provide more fully for thiamin (vitamin B_1) and iron, we have recommended also that of such amount of breadstuffs or cereals as one may choose to eat, at least half should be in the approximately "whole grain" forms. It should, perhaps, be here mentioned again that whereas vitamins A and C occur abundantly only in a relatively few types of food, vitamin B_1 (thiamin) has very wide natural distribution in plants and animals alike, so that any shortage of thiamin in a food supply not grossly deficient in total calories is chiefly the result of an undue dependence upon foods which have been denatured by artificial and excessive refining of some sort.

Note that this application of the newer knowledge of nutrition leaves half the food (whether in terms of calories or of cost) to the free choice of the individual. So there is ample room to "eat what you want while eating what you should."

One who has made oneself a wholehearted convert to the new scientific knowledge can then get its benefit without necessarily renouncing any particular article or type of food, and without any feeling of having calamitously or reprehensibly "broken training" when circumstances dictate an occasional departure from the new type of dietary; for if on some days it is impracticable to make as modern a selection of

food as is here recommended, one can even-up on some subsequent day or days. Some ups and downs from day to day need not cause anxiety: it is rather the good balance in the total of the week's or the month's food consumption that counts. And "good balance" need not mean a long period of elaborate calculation, or even of mental arithmetic. A moderate amount of such practice as the exercises suggested at the ends of the previous chapters will afford, taken thoughtfully, should enable one to acquire a sense of proportion in regard to foods and dietaries which will give the needed guidance without constant weighing, measuring, or calculation.

Recorded observations extending over a consecutive period of four years, leave the definite impression that one may eat among other people, accepting the food choices made by others to the full extent that business and social customs call for, not making oneself conspicuous or self-conscious, but so balancing in the meals which are under one's control (and in the choices which even conventional meals allow) that half of the total food calories will be taken in the form of fruits, vegetables, and milk, in accordance with the suggestion already made and discussed.

Freedom in the Choice of Food

An important factor in making nutritional knowledge fully effective is a realization that, as already explained in part, a wide freedom of choice of food is entirely compatible with the gaining of the benefits which the newer chemistry of nutrition offers.

Freeing of the mind from needless inhibitions in one's choices among foods helps one to a more effective use of scientific guidance in nutrition; and it is also worthwhile from the viewpoint of the pleasures of the palate. For, as an editorial writer has pointed out, "Beside the meeting of nutritional needs, eating has an immense vogue as an amusement."

Religious inhibitions in the use of food do not fall within

the scope of this book to discuss further than that the newer knowledge of food values makes it easier to provide full nutritional equivalents for any particular article of food which may be interdicted even permanently. It also gives added reassurance against fear of injury to health from omissions of particular foods at special times; for nutritionally the important point is the adequacy of the intake when considered in terms of fairly long units of time.

Sanitary considerations may also be given all due weight without significantly hampering our food choices. We say all due weight, because some people still labor under undue fears. Until recently, discussions of food and health have dwelt largely upon ways in which food may conceivably do injury. Public pressures for "pure food" legislation, and the resulting Federal and State laws, have been activated chiefly by fears of injury and fraud; and as embodied in statute have dealt mainly in prohibitions of adulteration and misbranding. And even with these laws in operation, far too many people still harrass themselves and hamper their use of nutritional knowledge by exaggerated fears of unsanitary qualities in food. Sad to say, there are also some purveyors of advice to the public who still harp upon the old chords of exaggerated fears and indignations. Moreover, some people do not yet fully realize that during the past thirty years, partly through the permanent accomplishments of the "pure food movement" and partly through the advances of nutritional knowledge, *the center of gravity of the problem of the relations of food to health and social welfare has shifted from sanitation to nutrition.*

This is not to say that all the sanitary problems of the food supply have been entirely solved. It is to say that sanitary practices and nutritional knowledge now stand at such points that the consumer who thinks of his food choices chiefly in terms of his fears is sadly behind the times; and that it is far wiser to think of our foods *primarily* in terms of what they can do *constructively* in the building of higher health. Inasmuch as the constructive health values of a

scientific choice of foods have been considerably emphasized throughout this book we must assume that the reader will bear them in mind when we now mention the considerations which may occasionally tend to divert our food consciousness back into its old unhappy channels. Obviously, consumers may sometimes have occasion to assert themselves, either directly or through their local health officers, in regard to proper standards of municipal housekeeping cleanliness in the retail handling of foods. Thirty to forty years ago there was need of greater cleanliness in slaughterhouses and on dairy farms: during the intervening years the conditions formerly complained of have been very generally corrected.

In America at least, the sanitary conditions surrounding the production and handling of milk have been so greatly improved in recent years, and are now so carefully and constantly safeguarded by the health authorities of most communities, that the consumer need no longer feel any special anxiety regarding the safety of the market milk supply.

Under the United States meat inspection law, Federal inspection of animals for slaughter and of the sanitary conditions of handling meat, governs the operations of establishments which engage in interstate commerce in meats or meat products. This inspection is quite thorough in most respects; but the Federal authorities have not found it feasible to include the microscopic examinations which would be necessary to exclude pork which is infested with trichinae. Nor have any local health officers, so far as we know. The consumer's protection from trichinosis depends, therefore, on individual insistence upon very thorough cooking of the flesh of swine in whatever form it is eaten. (Current reports of frequency of trichinosis indicate that this precaution is not yet as fully appreciated as it should be.)

Meat of local origin, which has not been subject to Federal inspection, must, of course, depend upon local standards for its sanitary safeguards.

In former years there was controversy as to what preservative substances might be added to foods and under what conditions. The question (or group of questions,—for each preservative should of course be judged individually after investigation of its own merits) was studied in considerable detail by the United States Department of Agriculture, both in its laboratories in Washington and through consultants working in their own laboratories in several universities; and the rulings based on the findings of these investigations have been followed for nearly a generation in the enforcement of the food laws without giving rise to any serious difference of legal or scientific opinion. Hence the question of preservatives may presumably be regarded as having been settled in the sense that it need no longer be carried as anxiety in the mind of the consumer, or bias one's choice of food.

Spray residues on fruits and vegetables constitute, however, a somewhat analogous problem which is not yet (1940) settled in the same sense. The problem is most prominent in the case of the apple, which tends to retain, on its surface and especially in the depression around the stem and in the roughness of the blossom end, an appreciable amount of the dry residue of the insecticides and fungicides with which it has been sprayed for the protection of the crop. Until less-toxic sprays or more thorough methods of commercial washing to remove spray residues are introduced, it may be wise for the consumer either to reject the entire skin of sprayed fruits and vegetables or to scrub very thoroughly in washing such foods before eating, and also to remove by means of a knife all parts which cannot be effectively reached in scrubbing.

The sanitary hazards of present-day food supply are therefore not of such nature as to interfere seriously with the choice of foods for their nutritive values.

Food allergies which render the people afflicted with them abnormally sensitive to one or more foods which are perfectly wholesome to normal people may seriously handicap

food choices in relatively rare cases. The services of a physician who specializes in allergy may be required to determine whether a person who thinks he "can't eat" some important article or type of food is suffering from a real allergy or only from an aversion or a whim.

In the vast majority of cases the dominant limitation upon the choice of food is lack of money to buy as much as all members of the family would like to eat of the foods of their choice. Here, education in the newer aspects of the nutritive values can do much to assist the individual or the family to get the maximum of satisfaction for the food expenditure, as we have sought to explain in the preceding chapter and the earlier pages of this one.

Further Consideration of Consumer Demand and the Consequent Adjustment of Food Production

There need be no fear about the ability of our farms to supply the extra fruit, vegetables, and milk that will be called for as more and more consumers shift the emphasis of their food choice in the direction which our newer knowledge of nutrition indicates.

We are informed by experts of the United States Department of Agriculture that the farmers of this country could readily increase many-fold their present production of practically any fruit or vegetable for which there is sufficient growth of consumer demand. Land and labor formerly devoted too exclusively to the growing of cotton, and for which "diversification" is now universally recognized as needed on grounds of business economics in any case, may well be devoted, in part or in rotation, to the growing of small fruits, melons, and fresh vegetables (often referred to in agricultural and economic terms as "truck crops"). Here there is an enormous potential resource for the meeting of a growing market demand for fruits and vegetables; and the growth of such consumer demand will be favorable to the farmer in two ways, by relieving him from financial dependence upon a single cash crop and by greatly improving the

home-grown food supply of the farm family. (The farmer's children cannot eat surplus cotton; but they can eat surplus cantaloupes, or greens, or tomatoes, or any of many other fruits and vegetables, with great benefit.)

Moreover, according to the findings of Dr. O. E. Baker of the United States Department of Agriculture, fruit occupies only from 1 to 2 per cent, and vegetables only about 4 per cent of the crop acreage in this country, so that production of both could be doubled or trebled without affecting the returns from other crops to any serious degree.

Some regions and some breeds of cattle are adapted to the production of meat and others to the production of milk; but it is also true that there are enormous areas of our most productive farm lands which can and do produce both meat and milk efficiently, and shift their emphasis toward the one or the other "according to the market," *i.e.*, to the consumer demand.

There are also other regions in which the most profitable agricultural alternatives are meat on the one hand and some fruit or vegetable on the other: *e.g.*, apples in the Northwest; and lettuce in Colorado, where they still speak of the partially converted cattlemen "who want to sow their lettuce-seed from the saddle."

The Federal agricultural experts have also made careful estimates of the relative amounts of human food produced by a given acreage of farm land, with separate consideration of plowed land and pasture land when animal production is involved. To enter fully into this important study of our present and potential food production resources would lead beyond the scope of this book. It suffices for our present purpose to say that fruits, vegetables, and milk are more advantageous crops for the farmer to produce than are their usual alternatives, so that the increasing emphasis upon these foods can not only be easily met by our farmers but will also be distinctly helpful to the normal evolution of American agriculture.

Whatever part political policy or statesmanship may play,

the science of nutrition will increasingly serve human progress through an ever better informed and more intelligent consumer demand in the daily choice and use of food.

This daily use of our science,—alike to "illuminate the mind" and to "ameliorate man's estate,"—is an opportunity and a responsibility in which each of us has a share.

EXERCISE

Write your own supplement to the foregoing discussion of how to make nutritional knowledge more effective.

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Appendix A

FATTY ACIDS

With few if any exceptions the fatty acids of natural fats contain even numbers of carbon atoms; for both their building-up and breaking down processes go on mainly, if not entirely, by steps which add or remove a two-carbon "link" at a time.

Also these fatty acids belong, so far as known, to one or another of five series: the saturated series, of which stearic acid is an example, in which the molecule has no "double bond"; the series which includes oleic acid, which is unsaturated to the extent of one double bond in the molecule; and three further-unsaturated series with, respectively, two, three, and four double bonds in the molecule.

All statements regarding the *occurrence* of fatty acids in fats are to be understood as meaning that the acid occurs as *glyceride* (triglyceride), perhaps accompanied by a trace of the same acid in a free state.

Saturated Fatty Acids

The saturated fatty acids constitute an homologous series of the type formula $C_nH_{2n}O_2$. The nutritionally important members of this series are:

Butyric acid, $CH_3\ (CH_2)_2\ COOH$ (or more simply written $C_4H_8O_2$), occurring chiefly in butter fat of which it constitutes about 5 to 6 per cent;

Caproic acid, $C_6H_{12}O_2$, occurring in milk fats and coconut oil;*

Caprylic acid, $C_8H_{16}O_2$, which also occurs in milk fats and coconut oil;

*As the melting point of coconut fat lies between ordinary temperate and tropical temperatures, this commodity is an oil as shipped from the Tropics which produce it while it is a soft solid when it appears in such markets as London and New York.

Capric acid, $C_{10}H_{20}O_2$, occurring in the fats of milk (butter), of the coconut, and of the spice bush;

Lauric acid, $C_{12}H_{24}O_2$, which occurs in butter, coconut and palm oils, and in higher proportion in the fat of the spice bush;

Myristic acid, $C_{14}H_{28}O_2$, which also occurs in the fats just named, and in small proportions in many plant and animal fats;

Palmitic acid, $C_{16}H_{32}O_2$, which occurs widely and abundantly in both animal and vegetable fats; and

Stearic acid, $C_{18}H_{36}O_2$, which also is widely distributed in both plant and animal fats, more abundantly in the hard fats of both groups. (While *stearin* as a scientific term is the name for the individual chemical substance, glyceryl tristearate, the triglyceride of stearic acid alone; the harder portion of a fat as pressed industrially may in commerce be called its stearin, *e.g.*, "beef stearin," "cottonseed stearin," etc.).

Unsaturated Fatty Acids

The best known fatty acids of the series $C_nH_{2n-2}O_2$ are:

Oleic acid, $C_{18}H_{34}O_2$, which occurs in nearly all fats and fatty oils; and

Erucic acid, $C_{22}H_{42}O_2$, long known as occurring in the seed fats of the cruciferous plants such as commercial rapeseed and mustardseed oils, and more recently found to occur also in marine animal oils.

Acids of the series $C_nH_{2n-4}O_2$, $C_nH_{2n-6}O_2$, and $C_nH_{2n-8}O_2$ are illustrated respectively by *linoleic acid*, $C_{18}H_{32}O_2$; *linolenic acid*, $C_{18}H_{30}O_2$; and *arachidonic acid*, $C_{20}H_{32}O_2$. These are the best known members of their respective series; but probably many others exist in nature. It is also quite probable that these well-established names may sometimes be applied inadvertently to unidentified isomers as well as to the individual substances originally isolated and named.

In the earlier chemical investigations of natural fats small amounts of these highly unsaturated fatty acids were doubtless often overlooked. Now that their apparent nutritional importance is stimulating re-investigation they are being found more widely distributed than previously reported, and new members are being added to this group.

Appendix B

DIGESTIVE ENZYMES

TABLE 25.—THE CHIEF DIGESTIVE ENZYMES AND THEIR ACTIONS

	Enzymes	Secreted By	Action
Act on Carbohydrates	Ptyalin (salivary amylase)	Salivary glands	Converts starch to maltose
	Amylopsin (pancreatic amylase)	Pancreas	Converts starch to maltose
	Invertase (Sucrase)	Intestinal mucosa	Converts sucrose to glucose and fructose
	Maltase	Intestinal mucosa	Converts maltose to glucose
	Lactase	Intestinal mucosa	Converts lactose to glucose and galactose
Act on Fats	Lipases	Gastric mucosa and pancreas	Split fats to fatty acids and glycerol
Act on Proteins	Pepsin	Gastric mucosa	Splits proteins to proteoses and peptones
	"Trypsin" (actually a group of enzymes)	Pancreas	Splits proteins to proteoses, peptones, polypeptides, and amino acids
	"Erepsin" (actually a group of enzymes)	Intestinal mucosa	Splits peptones to amino acids and ammonia

Appendix C

COMPOSITION AND NUTRITIVE VALUES OF FOODS

In the tabulation which follows the data are given uniformly for 100-gram portions of edible material: first is given the physical dimensions in terms of the most convenient household measure, and then the total energy value in Calories per 100 grams of the edible portion (E.P.); the protein, fat, carbohydrate, calcium, phosphorus, and iron contents are given in percentage; ascorbic acid in milligrams, thiamin and riboflavin in micrograms (sometimes called gamma, γ), and vitamin A values in International Units, per 100 grams of food.

Table 26 includes the dimensions, energy values, and percentages of protein, fat, and carbohydrate.

Table 27 shows the calcium, phosphorus, iron, ascorbic acid (vitamin C), thiamin (vitamin B_1), riboflavin (vitamin B_2 or G), and vitamin A values.

In constructing these tables we have sought to give due weight at every point to all the evidence which was available in November 1939, including many data in course of preparation for publication which we were enabled to consult through the courtesy of Dr. M. S. Rose and Dr. A. W. Thomas among other Columbia colleagues; and of Dr. L. E. Booher and Dr. H. E. Munsell of the Bureau of Home Economics, United States Department of Agriculture.

The guidance of such previous compilations as those of Atwater, Bryant, Langworthy, Chatfield and Adams in the publications of the U. S. Department of Agriculture, the well-known tables of Mrs. Rose and of Mrs. Waller, and the recent compilations of vitamin values by Bessey, by Eddy and Dalldorf, and by Williams and Spies, is gratefully acknowledged. Where discrepancies between the data of such authorities are too large, or numbers of observations too small, or the natural variability of

the material too great, to permit confidence in a single average figure at present we have either left a blank space which the reader may fill in the light of later knowledge, or have indicated a range not of extreme variation but of what now appears reasonable probability. The data thus summarized in Tables 26 and 27 represent much study of the available evidence. To attempt to indicate all sources of evidence would require a prohibitive amount of space.

TABLE 26.—PROTEIN, FAT, AND CARBOHYDRATE CONTENT AND ENERGY VALUE OF FOODS: EXPRESSED PER 100 GRAMS OF THE EDIBLE MATERIAL

FOOD	APPROXIMATE MEASURE	CALORIES	PROTEIN	FAT	CARBOHYDRATE
			grams	*grams*	*grams*
Almonds	¾ c.	647	21.0	54.9	17.3
Apple(s)	1 small, 2″ diameter	63	0.4	0.5	14.2
baked	½ large apple	150	0.4	0.5	36.0
pie	3″ sector, 9″ diameter	272	3.1	9.8	42.8
sauce	⅜ c.	157	0.2	0.8	37.2
Apricots, dried	½ c. packed	278	4.7	1.0	62.5
dried, stewed	⅓ c.	128	1.3	—	30.7
fresh	2–3 average	58	1.1	—	13.4
Artichoke, French	½, 3″ diameter, 4″ long	66	3.4	0.5	12.0
Asparagus	12 stalks, 5″ long	26	2.2	0.2	3.9
Avocado	½, 4″ long; or ⅔ c. ½″ cubes	219	2.1	20.1	7.4
Bacon, broiled	30–35 small slices	517	16.7	50.0	—
uncooked	10 slices, 1½″ x 4½″ x ⅛″	620	10.5	64.8	—
Banana(s)	1, 6½″ long; or ¾ c. sliced	99	1.2	0.2	23.0
Barley, entire	½ c.	355	10.5	2.2	72.8
pearled	½ c.	355	8.5	1.1	77.8
Beans, baked	½ c.	129	6.9	2.5	19.6
dried	½ c.	345	22.5	1.8	59.6
Lima, dried	⅔ c.	350	18.1	1.5	65.9
Lima, fr sh	⅝ c.	131	7.5	0.8	23.5
snap or string	¾ c., 1″ pieces	42	2.4	0.2	7.7

Table 26.—Protein, Fat, and Carbohydrate Content and Energy Value of Foods Expressed per 100 Grams of the Edible Material (*Continued*)

Food	Approximate Measure	Calories	Protein	Fat	Carbohydrate
			grams	*grams*	*grams*
Beef, corned, canned		274	26.3	18.7	—
dried	7 thin slices, 4″ x 5″	180	30.0	6.5	0.4
lean muscle		156	21.3	7.9	—
Beet(s), cooked	2, 2″ diam.; or ½ c. diced	40	2.3	0.1	7.4
raw		45	1.6	0.1	9.6
Beet greens	½ c. cooked	33	2.0	0.3	5.6
Biscuit, baking powder	5½ small biscuits	371	9.3	13.7	52.6
Blackberries		62	1.3	1.0	11.9
Blueberries	¾ c.	68	0.6	0.6	15.1
Bluefish		89	19.4	1.2	—
Bologna	1 piece, 2⅛″ diam., 1⅙″ thick	234	18.7	17.6	0.3
Bran	1½ c.	153	13.3	2.6	19.2
Brazil nuts		696	17.0	66.8	7.0
Bread, Boston brown	2 slices, 3″ diam., ⅞″ thick	296	6.0	6.3	54.0
rye	3⅓ slices, 3½″ x 4″ x ½″	254	9.0	0.6	53.2
white	4–5 slices	261	9.2	1.3	53.1
white, raisin		292	6.6	6.8	51.1
whole wheat	4–5 slices	245	9.7	0.9	49.7
whole wheat, raisin	4–5 slices	269	7.3	3.1	53.2
Broccoli	⅞ c. cooked; or 2 5″ stalks	37	3.3	0.2	5.5
Brussels sprouts	7 sprouts, 1½″ diam.; or ⅜ c.	58	[illegible].4	0.5	8.9

TABLE 26.—PROTEIN, FAT, AND CARBOHYDRATE CONTENT AND ENERGY VALUE OF FOODS: EXPRESSED PER 100 GRAMS OF THE EDIBLE MATERIAL (*Continued*)

FOOD	APPROXIMATE MEASURE	CALORIES	PROTEIN	FAT	CARBOHYDRATE
			grams	*grams*	*grams*
Buns	3–4 average	339	9.4	7.2	59.1
Butter	½ c., scant; or 10 sq., 1¼″ x 1¼″ x ¼″	733	1.0	81.0	—
Buttermilk	½ c. scant	33	3.3	0.5	3.9
Cabbage	1½ c., chopped, raw	29	1.4	0.2	5.3
Cantaloupe	½ c. balls; or ¼ melon, 5″ diam.	40	0.6	—	9.3
Carrots	¾ c., ½″ cubes	45	1.2	0.3	9.3
Cashew nuts	¾ c.	605	19.1	47.1	26.2
Cauliflower	1 c. chopped; or ⅓ head, 4½″ diam.	31	2.4	0.2	4.9
Celery stalk	¾ c. ¼″ pieces; or 4 med. stalks	22	1.3	0.2	3.7
Chard	⅓ c. cooked	25	1.4	0.2	4.4
Cheese,					
Cheddar type		410	24.4	34.4	0.6
cottage, skim	5½ tbsp.	102	23.2	1.0	—
cream	1⅙ packages, 2¾″ x 2⅛″ x ¾″	451	16.0	43.0	—
Parmesan	1¼ c.	385	34.8	27.3	—
Roquefort	3″ sector, 1″ thick, 6½″ diam.	376	21.4	32.3	—
Swiss		392	29.2	30.6	—
Cherries, canned		90	1.1	0.1	21.1
fresh	⅔ c.	68	1.1	0.5	14.8
Chestnuts		242	6.2	5.4	42.1
Chicken	½ med. broiler	109	21.5	2.5	—

TABLE 26.—PROTEIN, FAT, AND CARBOHYDRATE CONTENT AND ENERGY VALUE OF FOODS: EXPRESSED PER 100 GRAMS OF THE EDIBLE MATERIAL (*Continued*)

FOOD	APPROXIMATE MEASURE	CALORIES	PROTEIN	FAT	CARBOHYDRATE
			grams	*grams*	*grams*
Chocolate, milk	4 pieces, 3″ x 1″ x ⅛″	552	8.0	35.0	51.1
unsweetened	3½ squares	611	12.9	48.7	30.3
wafers, double with sugar filling	8 wafers, 2″ diam	494	4.9	21.0	71.4
Clams, long (soft shell)	10 clams	59	9.0	1.3	2.9
round	6 clams; or ⅓ c.	61	10.5	0.8	3.0
Cocoa, beverage	½ c. scant	92	3.7	4.5	9.2
powder	⅚ c.	497	21.6	28.9	37.7
Coconut, dried		566	4.3	41.0	44.5
fresh		590	5.7	50.6	27.9
Cod		79	18.7	0.5	—
Cole slaw	1¼ c.	125	1.9	10.8	5.0
Collards	½ c. cooked	41	4.0	0.6	7.3
Corn, canned	⅜ c.	98	2.8	1.2	19.0
fresh	½ c.; or 2 ears 6″ long	108	3.7	1.2	20.5
Cornflakes	3 c.	383	8.2	0.4	86.7
Cornmeal, cooked	⅜ c.	59	1.5	0.4	12.5
uncooked	⅔ c.	357	9.2	1.9	75.4
Corn syrup	¼ c.	340	—	—	85.0
Cottonseed oil	½ c.	900	—	100.0	—
Crabmeat	⅔ c.	79	15.8	1.5	0.7

TABLE 26.—PROTEIN, FAT, AND CARBOHYDRATE CONTENT AND ENERGY VALUE OF FOODS: EXPRESSED PER 100 GRAMS OF THE EDIBLE MATERIAL (*Continued*)

FOOD	APPROXIMATE MEASURE	CALORIES	PROTEIN	FAT	CARBOHYDRATE
			grams	*grams*	*grams*
Crackers, Graham	10 crackers, 2½″ x 2¾″ x ¼″	420	10.0	9.4	73.8
oyster		422	11.3	10.5	70.5
soda		413	9.8	9.1	73.1
Cranberries	1 c.	53	0.4	0.7	11.3
Cranberry sauce		233	—	0.3	57.5
Cream, thin	⅜ c.	198	2.8	18.5	4.5
thick	⅜ c.	381	2.2	40.0	3.5
Cucumbers	14 slices, ⅛″ thick, 1½″–2″ diam.	14	0.7	0.1	2.7
Currants, dried		322	2.4	1.7	74.2
fresh		61	1.6	0.4	12.7
Custard pie	2″ sector, 9″ diam.	178	4.2	6.3	26.1
Dandelion greens		52	2.7	0.7	8.8
Dates, dried	14 dates	347	2.1	2.8	78.4
Eggplant	1 c. diced; or 2 slices, 4″ diam., ⅜″ thick	29	1.1	0.2	5.5
Eggs, whole	2 medium	148	13.4	10.5	—
white	3½ whites	51	12.3	0.2	—
yolk	6½ yolks	363	15.7	33.3	—
Endive		24	1.6	0.2	4.0
Escarole (chicory)		21	1.6	0.3	2.9
Farina, cooked	½ c., scant	59	1.8	0.3	12.4
uncooked	⅝ c.	361	11.0	1.4	76.3

TABLE 26.—PROTEIN, FAT, AND CARBOHYDRATE CONTENT AND ENERGY VALUE OF FOODS: EXPRESSED PER 100 GRAMS OF THE EDIBLE MATERIAL (*Continued*)

FOOD	APPROXIMATE MEASURE	CALORIES	PROTEIN	FAT	CARBOHYDRATE
			grams	*grams*	*grams*
Fig(s), dried		317	4.3	0.3	74.2
fresh	3, 1½″ diam.	88	1.4	0.4	19.6
Fig bars	3½ bars	357	4.6	6.6	69.8
Filberts (Hazelnuts)	½ c.	702	15.6	65.3	13.0
Flounder, "sole"		62	14.2	0.6	—
Flour, rye	¾ c.	350	6.8	0.9	78.7
wheat, white	⅞ c. sifted	353	11.2	1.0	74.9
whole wheat	¾ c., scant	359	13.8	1.9	71.9
Frankfort sausages	2, 5¼″ long, 1″ diam.	250	19.6	18.6	1.1
Fudge, chocolate	4, 1″ cubes	372	2.0	7.6	74.0
Gelatin (powder)	10 tbsp.	366	91.4	0.1	—
Gingerale	½ c., scant	32	—	—	8.0
Gooseberries		47	0.8	0.4	10.1
Grape(s)	½ c.; or 20 grapes (Malaga size)	78	1.4	1.4	14.9
juice	½ c., scant	75	0.4	—	18.5
Grapefruit	½ c., ½″ pieces; or ½, 4″ diam.	44	0.5	0.2	10.1
juice	⅜ c.	42	0.4	0.1	9.8
Haddock, fresh		71	17.2	0.3	—
Halibut steak		121	18.6	5.2	—

TABLE 26.—PROTEIN, FAT, AND CARBOHYDRATE CONTENT AND ENERGY VALUE OF FOODS: EXPRESSED PER 100 GRAMS OF THE EDIBLE MATERIAL (*Continued*)

FOOD	APPROXIMATE MEASURE	CALORIES	PROTEIN	FAT	CARBOHYDRATE
			grams	*grams*	*grams*
Ham, fresh, lean		230	25.0	14.4	—
fresh, medium fat		321	15.3	28.9	—
smoked, boiled		282	20.2	22.4	—
smoked, lean		266	19.8	20.8	—
Hazelnuts, See Filberts					
Herring, fresh		142	19.5	7.1	—
smoked		298	36.9	15.8	—
Hickory nuts	½ c., chopped	714	15.4	67.4	11.4
Hominy, cooked	½ c.	82	2.2	0.2	17.8
uncooked	½ c.	355	8.3	0.6	79.0
Honey	¼ c.	326	0.4	—	81.2
Huckleberries, See Blueberries					
Ice cream, commercial vanilla	½ c.	219	2.5	15.1	18.2
Jelly, fruit	⅓ c.	313	1.1	—	77.2
Kale	1 c., cooked	50	3.9	0.6	7.2
Kidney, veal	½ c., cubed	125	16.9	6.4	—
Kohlrabi	½ to ¾ c., diced	36	2.1	0.1	6.7
Lamb chops, broiled	2 medium sized	356	21.7	29.9	—
leg, medium fat		225	19.2	16.5	—
leg, roasted		193	19.7	12.7	—
Lard	½ c.	900	—	100.0	—

TABLE 26.—PROTEIN, FAT, AND CARBOHYDRATE CONTENT AND ENERGY VALUE OF FOODS: EXPRESSED PER 100 GRAMS OF THE EDIBLE MATERIAL (*Continued*)

FOOD	APPROXIMATE MEASURE	CALORIES	PROTEIN	FAT	CARBOHYDRATE
			grams	*grams*	*grams*
Leeks		45	2.5	0.4	7.9
Lemon or juice	½ c.	44	0.9	0.6	8.7
Lentils, dried	½ c.	349	25.7	1.0	59.2
Lettuce	6 large leaves	18	1.2	0.2	2.9
Liver, beef		128	20.4	4.5	1.7
Lobster meat	¾ c., scant	84	18.1	1.1	0.5
Loganberries		69	1.0	0.6	15.0
Loganberry juice		43	0.6	—	10.1
Macaroni, cooked	½ c.	89	3.0	1.5	15.8
uncooked	1 c.; or 10 sticks, 9″ long	358	13.4	0.9	74.1
Macaroons		424	6.5	15.2	65.2
Mackerel, fresh		137	18.7	7.1	—
Maple syrup	¼ c.	286	—	—	71.4
Mayonnaise	½ c.	719	1.7	77.8	2.9
Milk, condensed, sweetened	⅛ c.	326	8.8	8.3	54.1
evaporated, unsweetened	⅛ c.	141	6.7	8.2	10.1
malted, dry	¾ c.	404	13.8	6.8	71.9
skimmed, dried		352	35.4	1.7	48.8
skimmed, fresh	½ c.	37	3.4	0.3	5.1
whole, dried	1 c.	512	26.9	28.7	36.5
whole, fresh	⅜ c.	69	3.3	4.0	5.0

TABLE 26.—PROTEIN, FAT, AND CARBOHYDRATE CONTENT AND ENERGY VALUE OF FOODS: EXPRESSED PER 100 GRAMS OF THE EDIBLE MATERIAL (*Continued*)

Food	Approximate Measure	Calories	Protein	Fat	Carbohydrate
			grams	*grams*	*grams*
Mince pie		286	5.8	12.3	38.1
Molasses, cane	⅓ c.	287	2.4	—	69.3
Muffins, 1 egg	2, average	285	8.3	8.7	43.0
whole wheat		245	7.4	2.5	48.3
Muskmelon		40	0.6	—	9.3
Mustard greens	⅝ c., cooked	28	2.3	0.3	4.0
Mutton, leg, lean		191	19.8	12.4	—
leg, roasted		303	25.0	22.6	—
Nectarines		67	0.5	0.1	16.0
Oatmeal, cooked	½ c.	66	2.7	1.2	11.1
uncooked	1⅓ c.	400	16.1	7.2	67.5
Okra	10–12 pods; or ½ c., canned	38	1.6	0.2	7.4
Oleomargarine	7 tbsp.	752	1.2	83.0	—
Olive oil	½ c.	900	—	100.0	—
Olives, green		300	1.1	27.6	11.6
ripe		250	1.7	25.0	4.3
Onions	3, 1½″ diam.; or ½ c., sliced	48	1.6	0.3	9.9
Orange(s)	1 small, 2½″ diam.	51	0.8	0.2	11.6
juice	½ c., scant	55	0.6	—	13.1
Oysters	4 large; or ⅓ c. solids	50	6.2	1.2	3.7
Papayas		43	0.6	0.1	10.0

TABLE 26.—PROTEIN, FAT, AND CARBOHYDRATE CONTENT AND ENERGY VALUE OF FOODS: EXPRESSED PER 100 GRAMS OF THE EDIBLE MATERIAL (*Continued*)

FOOD	APPROXIMATE MEASURE	CALORIES	PROTEIN	FAT	CARBOHYDRATE
			grams	*grams*	*grams*
Parsnips	½ c., cubes	65	1.6	0.5	13.5
Peaches, canned	1 large half plus 1½ tbsp. juice	47	0.7	0.1	10.8
dried		312	4.0	0.8	72.2
fresh	1 medium	51	0.5	0.1	12.0
Peanut(s), roasted	¾ c., shelled	548	25.8	38.6	24.4
Peanut butter	6 tbsp	604	29.3	46.5	17.1
Pears, canned	2 halves plus 2 tbsp. juice	76	0.3	0.3	18.0
fresh	1 large	70	0.7	0.4	15.8
Pea soup, canned	⅜ c.	51	3.6	0.7	7.6
Peas, canned, drained		47	3.0	0.2	8.3
canned, including liquor	½ c.	55	3.6	0.2	9.8
dried	½ c.	355	24.6	1.0	62.0
fresh green, shelled	¾ c.	101	6.7	0.4	17.7
Pecans, shelled	¾ c.	734	9.6	70.5	15.3
Peppers, green	1 pepper, 3–4″ long	29	1.2	0.2	5.7
Persimmons		141	0.8	0.4	33.5
Pineapple, canned	2 slices, 3 tbsp. juice	63	0.4	0.1	15.0
fresh	½ c., diced	58	0.4	0.2	13.7
juice, canned	½ c., scant	60	0.3	0.3	12.8
Plums	3, 1½″ diam.	56	0.7	0.2	12.9

TABLE 26.—PROTEIN, FAT, AND CARBOHYDRATE CONTENT AND ENERGY VALUE OF FOODS: EXPRESSED PER 100 GRAMS OF THE EDIBLE MATERIAL (*Continued*)

FOOD	APPROXIMATE MEASURE	CALORIES	PROTEIN	FAT	CARBOHYDRATE
			grams	*grams*	*grams*
Pork, loin, chops, medium fat..	1 med. chop, ½" thick	337	16.6	30.1	—
sausage	5 sausages, 3" long, ¾" diam., cooked	452	13.0	44.2	1.1
Potatoes	¾ c., riced; 1, 2½" diam	85	2.0	0.1	19.1
Prunes, dried	12 medium	301	2.1	—	73.3
stewed		125	0.6	—	30.6
Pumpkin(s), fresh	½ c., cooked	35	1.2	0.2	7.3
Radishes	10 red button	22	1.2	0.1	4.2
Raisins	¾ c.	345	2.6	3.3	76.1
Raspberries, black		83	1.5	1.6	15.6
red		67	1.1	0.6	14.4
Rhubarb		18	0.5	0.1	3.8
Rice, brown		354	8.0	2.0	76.0
white, cooked	½ c.	93	1.8	0.1	21.3
white, uncooked	½ c.	350	8.0	0.3	79.0
Rutabagas	⅔ c., ½" cubes	41	1.1	0.1	8.9
Salmon, canned		190	20.8	11.2	—
fresh		203	22.0	12.8	—
Sardines, canned		316	19.2	25.5	—
Sauerkraut	⅔ c.	27	1.7	0.5	3.8
Scallops	15–20	74	14.8	0.1	3.4
Shad, whole, fresh	Cross section, 3½" on back	161	18.8	9.5	—

TABLE 26.—PROTEIN, FAT, AND CARBOHYDRATE CONTENT AND ENERGY VALUE OF FOODS: EXPRESSED PER 100 GRAMS OF THE EDIBLE MATERIAL (*Continued*)

FOOD	APPROXIMATE MEASURE	CALORIES	PROTEIN	FAT	CARBOHYDRATE
			grams	*grams*	*grams*
Shad roe		128	20.9	3.8	2.6
Shredded wheat	3⅓ biscuits	366	10.5	1.4	77.9
Shrimp, canned (dry pack)	½–¾ c.	112	25.5	0.8	—
Smelts		87	17.6	1.8	—
Spinach	½ c., cooked	25	2.3	0.3	3.2
Squash, summer	½ c., cooked and mashed	19	0.6	0.1	3.9
winter	½ c., cooked and mashed	44	1.5	0.3	8.8
Squash pie	2″ sector, 9″ diam.	180	4.4	8.4	21.7
Strawberries	½–⅔ c.	41	0.8	0.6	8.1
Sturgeon		90	18.1	1.9	—
Sugar	½ c.	400	—	—	100.0
Sweetpotatoes		124	1.8	0.7	27.9
Tangerines	2, 2″ diam.	50	0.8	0.3	10.9
Tapioca, cooked	⅓ c.	55	0.1	—	13.7
uncooked	½ c.	355	0.4	0.1	88.0
Tomato	1, 2½″ diam.; or ⅜ c., canned	23	1.0	0.3	4.0
Tongue		158	18.9	9.2	—
Trout, brook		96	19.2	2.1	—
lake		164	17.8	10.3	—
Tuna fish	½ c.	208	26.6	11.4	—
Turkey		291	21.1	22.9	—

TABLE 26.—PROTEIN, FAT, AND CARBOHYDRATE CONTENT AND ENERGY VALUE OF FOODS: EXPRESSED PER 100 GRAMS OF THE EDIBLE MATERIAL (*Continued*)

FOOD	APPROXIMATE MEASURE	CALORIES	PROTEIN	FAT	CARBOHYDRATE
			grams	*grams*	*grams*
Turnip(s)	3/4 c., 1/2" cubes	35	1.1	0.2	7.1
Turnip greens	1/2 c., cooked	37	2.9	0.4	5.4
Veal, cutlet		150	20.3	7.7	—
leg		143	20.7	6.7	—
Vegetable soup, canned	3/8 c.	14	2.9	—	0.5
Walnuts, black	1 1/6 c., chopped	664	27.6	56.3	11.7
English	1 1/6 c., chopped	703	18.4	64.4	13.0
Watercress		23	1.7	0.3	3.3
Watermelon	1 slice, 2 1/2" x 2 1/2" x 1"	30	0.4	0.2	6.7
Wheat, entire		362	11.1	1.7	75.5
White sauce	1/8 c., generous	156	3.6	12.0	8.6
Zwieback	12 pieces, 3 1/4" x 1 1/4" x 1/2"	422	9.8	9.9	73.5

TABLE 27.—ESTIMATED APPROXIMATE AVERAGES FOR SOME OF THE MINERAL ELEMENTS AND VITAMIN VALUES OF FOODS: AMOUNTS, IN THE TERMS SHOWN AT THE HEADS OF THE RESPECTIVE COLUMNS, PER 100 GRAMS EDIBLE PORTION

FOOD	CALCIUM	PHOSPHORUS	IRON	ASCORBIC ACID (Vitamin C)	THIAMIN (Vitamin B_1)	RIBOFLAVIN (Vitamin G)	VITAMIN A VALUE
	gram	*gram*	*gram*	*milligrams*	*micrograms*	*micrograms*	*International Units*
Almonds	.252	.451	.0039	—	120–240		580
Apple(s)	.007	.012	.00036	5–8	20–55		40–100
baked	.007	.013	.0003	1–2	(20)		(60)
pie	.009	.026	.0004	(1)	(20)		(60)
sauce	.005	.009	.0002	3–4	(20)		(60)
Apricots, dried	.065	.120	.0076	2–12	60–120	240–300	6,000–15,000
dried, stewed	(.02)	(.03)	(.002)		(15–30)	(40–50)	(1,500–3,000)
fresh	.013	.024	.0006	1–3.5	25–35	105	3,000–8,000
Artichoke, French	.040	.094	.00095	9	+		150–300
Asparagus	.021	.040	.0010	15–40	150–180	++	300–700
Avocado	.045	.044	.0063	2–8	100–200	140	110

N.B. (1) Where a range is given, this is *not the extreme range* of reported data: it is an attempt to suggest reasonable boundaries for the zone within which the *average* may be expected to fall when adequately established. Caution should be exercised in accepting as representative or standard or average, a figure outside of the range. In lack of other guide, it may be well in calculations to use a value near the middle of the range when the food is eaten raw; and the minimum of the range when the food is cooked.

(2) Data enclosed in parentheses are based on evidence less direct than in the majority of cases.

(3) A dash (—) means that the amount present, if any, is probably negligible.

(4) A plus mark (+) means present in significant amount, but not measured as to quantity (++ and +++ indicate more).

(5) A blank space means that satisfactory data were not at hand when the table was made. This may be because of lack of chemical laboratory determinations of the element or the vitamin value in the particular food; or because proportions used in cookery or adopted in servings are largely matters of local, or of changing custom.

(6) In this table, the printing of a single figure for any given *vitamin* value implies that not enough cases have been reported to justify an estimate of range.

TABLE 27.—ESTIMATED APPROXIMATE AVERAGES FOR SOME OF THE MINERAL ELEMENTS AND VITAMIN VALUES OF FOODS: AMOUNTS, IN THE TERMS SHOWN AT THE HEADS OF THE RESPECTIVE COLUMNS, PER 100 GRAMS EDIBLE PORTION (*Continued*)

FOOD	CALCIUM	PHOSPHORUS	IRON	ASCORBIC ACID (Vitamin C)	THIAMIN (Vitamin B_1)	RIBOFLAVIN (Vitamin G)	VITAMIN A VALUE
	gram	*gram*	*gram*	*milligrams*	*micrograms*	*micrograms*	*International Units*
Bacon, broiled	.013	.248	.0035	—	(100)	105	
uncooked	.006	.108	.0015	—	(100)	75–125	
Banana(s)	.008	.028	.00064	7–8	50–100	45–80	160–400
Barley, entire	.051	.400	.00475	—	400–500	+	71
pearled	.020	.181	(.002)	—	(180)		
Beans, baked	.062	.185	.0020	—	132	+	40–70
dried	.148	.463	.0105	—	315–510	+	
Lima, dried	.072	.386	.0097	—	450–600	790	+
Lima, fresh	.028	.133	.0024	15–35	250–350	250	+
snap or string	.055	.050	.00116	10–20	55–95	65–150	600–1,800
Beef, corned, canned	.013	.119	.0098	—	+	++	
dried	.018	.326	.0045	—	+	++	
lean muscle	.013	.204	.0030	—	110–210	180–260	10–50
Beet greens	.094	.040	.00324	35		625	++
Beets	.028	.042	.00085	3–5	25–95	125	<100
Biscuit, baking powder	.062	.097	.00055	—	7–10	65	
Blackberries	.017	.019	.0009	3	<25		80–300
Blueberries	.025	.020	.0009	4–10	45	15	20–80
Bluefish	.021	.224	.0011	—	+	+	

(4) A plus mark (+) means present in significant amount, but not measured as to quantity (++ and +++ indicate more).

TABLE 27.—ESTIMATED APPROXIMATE AVERAGES FOR SOME OF THE MINERAL ELEMENTS AND VITAMIN VALUES OF FOODS: AMOUNTS, IN THE TERMS SHOWN AT THE HEADS OF THE RESPECTIVE COLUMNS, PER 100 GRAMS EDIBLE PORTION (*Continued*)

FOOD	CAL-CIUM	PHOS-PHORUS	IRON	ASCORBIC ACID (Vitamin C)	THIAMIN (Vitamin B1)	RIBOFLAVIN (Vitamin G)	VITAMIN A VALUE
	gram	*gram*	*gram*	*milligrams*	*micrograms*	*micrograms*	*International Units*
Bologna	.003	.060	.0028	—	+	+	+
Bran	.113	.893	.0168	—	234–700	+	138
Brazil nuts	.123	.602	.0028		++		+
Bread, Boston brown	.129	.185	.0030	—	125–170	70	
rye	.024	.148	.0016	—	90–190	+	
wheat, white	.031	.097	.0008	—	55–85	40–100	
white raisin	.053	.088	.0008	—	(80)	45	
whole wheat	(.05)	(.15)	(.002)	—	240–400	100	
whole wheat, raisin	.055	.154	.0019	—	(300)	(100)	88
Broccoli	.140	.068	.00137	50–130	80–100	200–500	3,000–9,000
Brussels sprouts	.027	.121	.00117	13–50	171	+	300–500
Buns	.016	.079	.0007	—			
Butter	.016	.017	.0002	—	—	—	3,500–5,000
Buttermilk	.105	.097	.003	1–2	15–50	80	
Cabbage, headed	.046	.034	.00043	30–40	70–140	65-135	30–80
loose leaf	.429	.072	.0018				880
Cantaloupe	.016	.015	.00039	26–34	50–65	75	400–2,400
Carrots	.045	.041	.00064	3–5	60–140	75–125	2,200–4,000
Cashew nuts	.048	.480		—	+		

(4) A plus mark (+) means present in significant amount, but not measured as to quantity (++ and +++ indicate more).

TABLE 27.—ESTIMATED APPROXIMATE AVERAGES FOR SOME OF THE MINERAL ELEMENTS AND VITAMIN VALUES OF FOODS: AMOUNTS, IN THE TERMS SHOWN AT THE HEADS OF THE RESPECTIVE COLUMNS, PER 100 GRAMS EDIBLE PORTION (*Continued*)

FOOD	CALCIUM	PHOSPHORUS	IRON	ASCORBIC ACID (Vitamin C)	THIAMIN (Vitamin B_1)	RIBOFLAVIN (Vitamin G)	VITAMIN A VALUE
	gram	*gram*	*gram*	*milligrams*	*micrograms*	*micrograms*	*International Units*
Cauliflower	.022	.060	.00094	48–94	130–200	150–220	35–60
Celery stalk	.078	.046	.00062	6–8	20–50	30–55	5–50
Chard	.100	.050	.00309	10–20		+	13,000–27,000*
Cheese, Cheddar type	.930	.701	.0013	—	40–50	450–600**	2,000–4,000
cottage, skim	.082	.263			+		60–80
cream	(.36)	(.26)	(.0005)		15–20	100–120	++
Parmesan	(1.35)	(1.00)	(.002)	—	22–30	450–600**	1,200–1,500
Roquefort	(.75)	(.6)	(.002)	—	+	(+)	(+)
Swiss	(1.09)	(.8)	(.002)	—	30	450–600**	(+)
Cherries, canned	(.01)	(.02)	.0003	6			(+)
fresh	.019	.030	.0004	8–10	51		+
Chestnuts	.032	.094	.0007	—	170–280		
Chicken	.013	.232	.0032	—	90–380	100–200	+
Chocolate	.091	.453	.0027	—	75		
Clams, long	.123	.105	.0041		+	(15)	10–30
round	.095	.093	.0044		+	(15)	10–30

(4) A plus mark (+) means present in significant amount, but not measured as to quantity (++ and +++ indicate more).

* Data for "Greens" (Table 18) used for Chard, Dandelion, Escarole, Kale, Mustard greens, Spinach, and Turnip tops.

** The relatively few data for Cheddar type, Parmesan, and Swiss cheeses are here averaged together, as to riboflavin content.

TABLE 27.—ESTIMATED APPROXIMATE AVERAGES FOR SOME OF THE MINERAL ELEMENTS AND VITAMIN VALUES OF FOODS: AMOUNTS, IN THE TERMS SHOWN AT THE HEADS OF THE RESPECTIVE COLUMNS, PER 100 GRAMS EDIBLE PORTION (*Continued*)

FOOD	CAL-CIUM	PHOS-PHORUS	IRON	ASCORBIC ACID (Vitamin C)	THIAMIN (Vitamin B_1)	RIBOFLAVIN (Vitamin G)	VITAMIN A VALUE
	gram	*gram*	*gram*	*milligrams*	*micrograms*	*micrograms*	*International Units*
Cocoa, beverage*	.124	.110	.0003	1	40–60	(200)	(200)
Coconut, dried	.059	.155	(.005)	—	(100–200)	++	
fresh	.024	.074	.0018		70–100	++	
Coconut custard pie	(.08)	(.10)	(.001)	0.5	30	155	+
Cod	(.01)	(.185)	(.003)	—	27–120	+	11
Cole slaw	(.04)	(.03)	(.0004)	2–20	57	+	
Collards	.202	.074	.00166	30–60	150–250	250	2,000–6,000
Corn, canned	(.007)	(.10)	(.0004)	6	(100)		**
maize, dry	.029	.281	.00364	—	200–300	+	**
Corn meal	.016	.152	.0009	—	50–300	80	**
Corn, sweet	.006	.103	.00047	8–11	120–150	+	**
sweet, dried	.021	.376	.0029		(+)	+	**
Cornflakes	(.014)	(.114)	(.0027)	—			—
Corn syrup, dark	(.06)	(.01)	(.0014)	—			—
light	(.01)	—	(.0003)	—	—		—
Crabmeat	(.016)	(.18)	(.001)	—	+		

(4) A plus mark (+) means present in significant amount, but not measured as to quantity (++ and +++ indicate more).

* Made with milk.

** Significant vitamin A values in the yellow, but not in the white varieties. Yellow corn meal reported to have 700-750 International Units per 100 grams.

Table 27.—Estimated Approximate Averages for Some of the Mineral Elements and Vitamin Values of Foods: Amounts, in the Terms Shown at the Heads of the Respective Columns, per 100 Grams Edible Portion (*Continued*)

Food	Calcium	Phosphorus	Iron	Ascorbic Acid (Vitamin C)	Thiamin (Vitamin B_1)	Riboflavin (Vitamin G)	Vitamin A Value
	gram	*gram*	*gram*	*milligrams*	*micrograms*	*micrograms*	*International Units*
Crackers, graham	(.02)	(.20)	(.002)	—	+		
white	(.02)	(.10)	(.002)	—			
Cranberries	.013	.011	.00044	10–13			10–20
Cranberry sauce	(.017)	(.01)	(.0004)	(5–10)			(10–20)
Cream, thick (40% fat)	(.09)	(.07)	(.0001)	1–1.5	(25–35)	(120–180)	2,000–2,500
thin (18.5% fat)	(.10)	(.09)	(.0002)	1–2	(30–40)	(150–200)	1,000–1,500
Cucumbers	.006	.018	.00033	2–13	90	150	15–50
Currants, dried	.082	.195	.0040	—			
fresh, red	.026	.038	.00063	15–20			
Custard pie, see Coconut							
Dandelion	.084	.035	.00305	5–40	150–225		13,000–27,000*
Dates, dried	.070	.056	.00356	—	60–100		60–300
Eggplant	.011	.031	.0005	1–9	40–100		20–100
Eggs	.063	.224	.00313	—	140–160	280–420	1,000–2,000
Egg white	.013	.015	.0001	—	trace	150–300	trace
Egg yolk	.135	.593	.0086	—	350–440	380–750	2,500–5,000
Endive	.104	.039	.00123	10–14	99	235	
Escarole	.029	.027	.00153	6–10		75–400	13,000–27,000*

(4) A plus mark (+) means present in significant amount, but not measured as to quantity (++ and +++ indicate more).
* Data for "Greens" (Table 18) used for Chard, Dandelion, Escarole, Kale, Mustard greens, Spinach, and Turnip tops.

TABLE 27.—ESTIMATED APPROXIMATE AVERAGES FOR SOME OF THE MINERAL ELEMENTS AND VITAMIN VALUES OF FOODS: AMOUNTS, IN THE TERMS SHOWN AT THE HEADS OF THE RESPECTIVE COLUMNS, PER 100 GRAMS EDIBLE PORTION (*Continued*)

FOOD	CALCIUM	PHOSPHORUS	IRON	ASCORBIC ACID (Vitamin C)	THIAMIN (Vitamin B_1)	RIBOFLAVIN (Vitamin G)	VITAMIN A VALUE
	gram	*gram*	*gram*	*milligrams*	*micrograms*	*micrograms*	*International Units*
Figs, dried	.161	.116	.00287	—	80–180	85–125	50–90
fresh	.053	.036	(.0009)	2	80–100	82	60–90
Flounder (sole)	(.037)	(.16)	(.001)	—	+		
Flour, rye	.018	.289	.0013	—	165–220	60	
white	.015	.101	.0010	—	60–100	40	—
whole wheat	.035	.306	.0035	—	330–500	100–200	
Frankforters	(.01)	(.22)	(.0025)	—	+	+	
Fudge	(.04)	(.06)	(.0004)	—	—	—	
Gooseberries	.035	.031	.0005	25			
Grapefruit (or juice)	.021	.020	.0003	38–41	50–100	20–100	21
Grape juice	.011	.010	.0003		(30–60)		
Grapes	.019	.035	.0007	2–3	30–60		20–60
Guavas	(.02)	(.02)	(.0003)	60–100	40–55	88	200
Haddock	(.018)	(.20)	(.001)	—	+	+	7
Halibut	(.01)	(.20)	(.001)	—	84–180	+	
Ham, lean	(.02)	(.24)	(.003)	—	600–1,428	200–300	
Hazelnuts	.287	.354	.0041	—	300–500		440
Herring, fresh	(.02)	(.22)	(.001)	—	+		
smoked	(.04)	(.44)	(.002)	—	+		

(4) A plus mark (+) means present in significant amount, but not measured as to quantity (++ and +++ indicate more).

TABLE 27.—ESTIMATED APPROXIMATE AVERAGES FOR SOME OF THE MINERAL ELEMENTS AND VITAMIN VALUES OF FOODS: AMOUNTS, IN THE TERMS SHOWN AT THE HEADS OF THE RESPECTIVE COLUMNS, PER 100 GRAMS EDIBLE PORTION (*Continued*)

FOOD	CALCIUM	PHOSPHORUS	IRON	ASCORBIC ACID (Vitamin C)	THIAMIN (Vitamin B_1)	RIBOFLAVIN (Vitamin G)	VITAMIN A VALUE
	gram	*gram*	*gram*	*milligrams*	*micrograms*	*micrograms*	*International Units*
Hominy	.011	.070	(.0009)	—			
cooked	(.002)	(.015)	(.0002)	—			
Honey	.005	.018	.0007	—	—	—	—
Huckleberries, See Blueberries							
Ice Cream**	(.08)	(.06)	(.002)	1	(10)	55	(600)
Kale	.181	.067	.00254	50–100	120–190	400–600	13,000–27,000*
Kidney	(.01)	(.18)	(.004)	—	400–500	1,700–2,200	500–1,000
Kohlrabi	.078	.057	.0007	40–80	40–70		
Lamb, chop	(.01)	(.22)	(.003)	—	200–300		
leg of	.011	.207	.0015	—		280	
Leeks	.058	.056	.0007	10–20	96		
Lemon (or juice)	.022	.011	.0006	52–60	30–90		
Lentils, dry	.102	.383	.0086	—	300–600	190	
Lettuce, headed	.017	.040	.0005	6–21	50–125	100–240	70–700
loose leaf	.069	.028	.0015				700–7,000
Liver	.011	.368	.0082	+	300–420	1,800–2,600	5,000–10,000
Lobster	(.06)	(.28)	(.001)				

(4) A plus mark (+) means present in significant amount, but not measured as to quantity (++ and +++ indicate more).
* Data for "Greens" (Table 18) used for Chard, Dandelion, Escarole, Kale, Mustard greens, Spinach, and Turnip tops.
** May vary between the values here given and those of the fruits which it may contain.

TABLE 27.—ESTIMATED APPROXIMATE AVERAGES FOR SOME OF THE MINERAL ELEMENTS AND VITAMIN VALUES OF FOODS: AMOUNTS, IN THE TERMS SHOWN AT THE HEADS OF THE RESPECTIVE COLUMNS, PER 100 GRAMS EDIBLE PORTION (*Continued*)

FOOD	CALCIUM	PHOSPHORUS	IRON	ASCORBIC ACID (Vitamin C)	THIAMIN (Vitamin B_1)	RIBOFLAVIN (Vitamin G)	VITAMIN A VALUE
	gram	*gram*	*gram*	*milligrams*	*micrograms*	*micrograms*	*International Units*
Loganberries	.035	.022	.0014	+	+		
Macaroni, cooked	.004	.024	.0002	—	(5–10)		
dry	.022	.144	.0012	—	25–50		
Mackerel	.011	.273	(.001)	—	+		
Mangoes	.005	.018	.0003	+++	40–100	200–260	1,000–2,000
Maple syrup	.107	.013	(.003)	—	—		—
Mayonnaise	.016	.031	(.004)			55	
Milk, cow's	.118	.093	.0002	2.1–2.2	40–65	195–240	160–225
evaporated	(.24)	(.20)	(.0004)		50–80	330	300–450
dry skim	(1.18)	(.93)	(.002)		375	+++	
dry whole	(.94)	(.74)	(.0016)		315	1,300–1,900	1,300–1,800
malted	.357	.345	.0021		340	500	++
Molasses*	.258	.030	.0073	—	—	—	—
Muffins (made with egg)	(.08)	(.11)	(.001)	—	15–20	115	(250)
whole wheat	(.11)	(.13)	(.003)	—	90–120	75	(80)
Mushrooms	.014	.098	.0007	3–6	100–200		—
Muskmelon	.016	.015	.00039	26–34	50–65	75	200–2,400

(4) A plus mark (+) means present in significant amount, but not measured as to quantity (++ and +++ indicate more).

* Data here given are for genuine (sugar-house) molasses, the mother liquor from the crystallization of raw cane sugar; not to be confused with "syrups."

TABLE 27.—ESTIMATED APPROXIMATE AVERAGES FOR SOME OF THE MINERAL ELEMENTS AND VITAMIN VALUES OF FOODS: AMOUNTS, IN THE TERMS SHOWN AT THE HEADS OF THE RESPECTIVE COLUMNS, PER 100 GRAMS EDIBLE PORTION (*Continued*)

FOOD	CALCIUM	PHOSPHORUS	IRON	ASCORBIC ACID (Vitamin C)	THIAMIN (Vitamin B_1)	RIBOFLAVIN (Vitamin G)	VITAMIN A VALUE
	gram	*gram*	*gram*	*milligrams*	*micrograms*	*micrograms*	*International Units*
Mustard greens	.221	.066	.005		138	375	13,000–27,000*
Mutton	(.014)	(.216)	(.002)	—	200–300	(280)	
Nectarines	.005	.022	.0005				1,000–2,000
Oatmeal (dry)	.065	.387	.0048	—	345–770	(200)	
cooked	(.012)	(.07)	(.0009)	—	50–135	(30)	
Okra	.075	.053	.0006	10	126		300–600
Oleomargarine	(.02)	(.02)	(.0002)	—	—	—	
Olive oil	—	—	—	—	—	—	20–30
Olives, green	.122	.014	.0029		8		388
ripe	.122	.014	.0029		(8)		346
Onions	.041	.047	.00048	7–11	25–100	28–62	"negligible"
Orange (or juice)	.024	.018	.0004	52–56	75–145	28–90	50–400
Oysters	.056	.150	.0058	3	200–300		150–300
Papayas	.018	.013	.0003	33–55	15–30	83	2,000–3,000
Parsnips	.060	.076	.00077		120–190		
Peaches, canned	.009	.013	.0002	3–5			
dried	.060	.119	.006			150–250	1,500–6,000
fresh, white } fresh, yellow }	.010	.019	.00033	7–10	20–70	45	0–100
							1,000–2,000

* Data for "Greens" (Table 18) used for Chard, Dandelion, Escarole, Kale, Mustard greens, Spinach, and Turnip tops.

TABLE 27.—ESTIMATED APPROXIMATE AVERAGES FOR SOME OF THE MINERAL ELEMENTS AND VITAMIN VALUES OF FOODS: AMOUNTS, IN THE TERMS SHOWN AT THE HEADS OF THE RESPECTIVE COLUMNS, PER 100 GRAMS EDIBLE PORTION (*Continued*)

FOOD	CALCIUM	PHOSPHORUS	IRON	ASCORBIC ACID (Vitamin C)	THIAMIN (Vitamin B_1)	RIBOFLAVIN (Vitamin G)	VITAMIN A VALUE
	gram	*gram*	*gram*	*milligrams*	*micrograms*	*micrograms*	*International Units*
Peanut(s), roasted	.067	.395	.0020	—			
Peanut butter	(.067)	(.395)	(.0020)	—	500–600	200–500	360
Pears, canned	.009	.018	.0002		(30)		
fresh	.015	.018	.00032	3–5	30–95	20–150	10–15
Pea soup	(.092)	(.088)	(.0008)	0–1	10–15	100–200	300–400
Peas, canned, drained	.016	.106	.0013				
canned, including liquor	.014	.070	.0011	2–10	200–300	80–200	++
dried	.077	.411	.0057		300–620	250–380	+
fresh, green	.023	.127	.00207	15–25	270–495	250	1,000–1,300
Pecans	.089	.335	.0026	—	150–250		100–200
Peppers, green	.012	.028	.00040	90–150	20–30		++
Persimmons	.022	.021	.00027				
Pineapple, canned	.005	.009	.0003	10	63	20–30	20–30
fresh	.008	.011	.00037	13–25	80–125	50–80	40–60
Pineapple juice, canned	(.01)	(.01)	(.0001)	5–10	50–100	20–30	40–60
Plums	.020	.027	.00056	4–7	48–200		
Pork, lean	.006	.108	.0015	—	700–1,400	225–255	
lean, cooked	(.016)	(.32)	(.005)	—	300–900	(200)	
Pork liver	.011	.368	.0082		(500)	2,300	(8,000)

(4) A plus mark (+) means present in significant amount, but not measured as to quantity (++ and +++ indicate more).

TABLE 27.—ESTIMATED APPROXIMATE AVERAGES FOR SOME OF THE MINERAL ELEMENTS AND VITAMIN VALUES OF FOODS; AMOUNTS, IN THE TERMS SHOWN AT THE HEADS OF THE RESPECTIVE COLUMNS, PER 100 GRAMS EDIBLE PORTION (*Continued*)

FOOD	CALCIUM	PHOSPHORUS	IRON	ASCORBIC ACID (Vitamin C)	THIAMIN (Vitamin B_1)	RIBOFLAVIN (Vitamin G)	VITAMIN A VALUE
	gram	*gram*	*gram*	*milligrams*	*micrograms*	*micrograms*	*International Units*
Pork sausage	(.002)	(.027)	(.001)		++		
Potatoes	.013	.053	.00102	7–15	95–165	40–80	30–50
Prunes, dried	.058	.085	.00285	0–8	175–225	50–650	400–2,400
dried, stewed	(.02)	(.03)	(.001)	(0–2)	(60–80)	(20–200)	(100–800)
Pumpkin	.023	.046	.00093	5		100	++
Pumpkin pie	(.06)	(.09)	(.001)		35–45	100–120	300–400
Radishes	.031	.031	.00083	12–20	50–100		"negligible"
Raisins	.060	.132	.00299	—	100–200	125	10–100
Raspberries	.024	.027	.00088	8–15	<25		130
Raspberry juice	.024	.012	(.0008)	(8–15)			
Rhubarb	.044	.018	.00056	12–24	<25		100
Rice, entire	.065	.336	.0020	—	240–300		50–100
white	.011	.099	.0009	—	30–40		—
white, cooked	(.003)	(.025)	(.0003)	—			—
Rutabaga, See Turnip							
Salmon, fresh	.013	.242	(.001)	—	+	+	20–600
canned	.067	.286	.0013	—	+	200	20–600
Sardines, canned	.035	.365	.0018	—	90		
Sauerkraut	.039	.009	.0033	0–10	<30		25

(4) A plus mark (+) means present in significant amount, but not measured as to quantity (++ and +++ indicate more).

TABLE 27.—ESTIMATED APPROXIMATE AVERAGES FOR SOME OF THE MINERAL ELEMENTS AND VITAMIN VALUES OF FOODS: AMOUNTS, IN THE TERMS SHOWN AT THE HEADS OF THE RESPECTIVE COLUMNS, PER 100 GRAMS EDIBLE PORTION (*Continued*)

FOOD	CALCIUM	PHOSPHORUS	IRON	ASCORBIC ACID (Vitamin C)	THIAMIN (Vitamin B_1)	RIBOFLAVIN (Vitamin G)	VITAMIN A VALUE
	gram	*gram*	*gram*	*milligrams*	*micrograms*	*micrograms*	*International Units*
Scallops, steamed	.117	.040	.003	—	+		
Shad	(.02)	(.20)	(.001)	—	+		
Shad roe	.023	.242	.0012	—	200–300		2,000–3,000
Shredded wheat	.041	.324	.0045	—	+	+	
Shrimp	.094	.172	.0014	—	90		
Smelts	.014	.202	.001	—	+		
Spinach	.078	.046	.00255	15–50	95–155	250–400	13,000–27,000*
Squab	.012	.202	.0028	—	+		
Squash, white flesh	.018	.015	.00035	3	42	81	200–400
yellow flesh	.019	.028	.00055	3	48	81	2,000–4,000
Strawberries	.034	.028	.00068	25–50	<25		60–90
Sturgeon	.039	.264	.002	—	+		
Sugar	—	—	—	—	—	—	—
Sweetpotato	.020	.045	.00077	7–15	90–135	80–100	1,000–5,000
Tangerines	.041	.018	.0003	25–50	120		350
Tapioca	.016	.006	.0016	—	—		

(4) A plus mark (+) means present in significant amount, but not measured as to quantity (++ and +++ indicate more).

* Data for "Greens" (Table 18) used for Chard, Dandelion, Escarole, Kale, Mustard greens, Spinach, and Turnip tops.

TABLE 27.—ESTIMATED APPROXIMATE AVERAGES FOR SOME OF THE MINERAL ELEMENTS AND VITAMIN VALUES OF FOODS: AMOUNTS, IN THE TERMS SHOWN AT THE HEADS OF THE RESPECTIVE COLUMNS, PER 100 GRAMS EDIBLE PORTION (*Continued*)

FOOD	CALCIUM	PHOSPHORUS	IRON	ASCORBIC ACID (Vitamin C)	THIAMIN (Vitamin B_1)	RIBOFLAVIN (Vitamin G)	VITAMIN A VALUE
	gram	*gram*	*gram*	*milligrams*	*micrograms*	*micrograms*	*International Units*
Tomato(es)	.007	.021	.0004	21–24	70–115	37–63	500–1,200
juice	.007	.015	(.0004)				
ketchup	.012	.018	.0008		+	+	—
soup, cream	(.09)	(.09)	(.0008)	10–15	40–50	100–150	400–600
Tongue	.030	.119	.0069	—	+	+	
Trout, raw	.018	.202	.001	—	87		
steamed	.037	.268	.001	—	87		
Tunafish	.034	.290	.0014	—	+		
Turkey, dark meat	.023	.422	.0059	—	+		
light meat	.021	.374	.0052	—	+		
Turnip(s)	.056	.047	.00052	20–30	65–95	50–100	10–20
Turnip greens	.347	.049	.00348	20–60	138–180	750	13,000–27,000*
Veal, cutlet, broiled	.014	.229	.0030	—	(150)	+	
leg, lean	.014	.229	.0026	—	(150)	375	
Vegetable soup, thick	.018	.026	.0005	1–3	5–10	30–40	150–250
Vinegar (cider)	.016	.013	(.0003)				
Walnuts	.089	.358	.0021	—	300–600		100–150
Watercress	.157	.046	.00297	43–66	100–150	150–300	800–3,000

(4) A plus mark (+) means present in significant amount, but not measured as to quantity (++ and +++ indicate more).

* Data for "Greens" (Table 18) used for Chard, Dandelion, Escarole, Kale, Mustard greens, Spinach, and Turnip tops.

TABLE 27.—ESTIMATED APPROXIMATE AVERAGES FOR SOME OF THE MINERAL ELEMENTS AND VITAMIN VALUES OF FOODS: AMOUNTS, IN THE TERMS SHOWN AT THE HEADS OF THE RESPECTIVE COLUMNS, PER 100 GRAMS EDIBLE PORTION (*Continued*)

FOOD	CALCIUM	PHOSPHORUS	IRON	ASCORBIC ACID (Vitamin C)	THIAMIN (Vitamin B_1)	RIBOFLAVIN (Vitamin G)	VITAMIN A VALUE
	gram	*gram*	*gram*	*milligrams*	*micrograms*	*micrograms*	*International Units*
Watermelon	.007	.013	.00023	6–8	30–40	30–40	50–100
Wheat, entire	.053	.374	.0050	—	500–660	100–220	20–25
Wheat germ	.071	(1.0)	(.007)	—	2,000–4,000	600–800	
Wine	.009	.015	(.0003)				
Yeast, baker's cake				—	270–700	600–3,000	
baker's, dried				—	1,000–3,000	2,000–4,000	
brewer's dried				—	5,000–8,000	2,500–4,700	

Appendix D

PRINCIPAL ACIDS OF TYPICAL FRUITS

Table 28 shows the percentages of the chief acids as determined in typical fruits by Hartmann and Hillig (*J. Assoc. Official Agricultural Chemists* 17, 522-531).

TABLE 28.—PERCENTAGES OF CERTAIN ACIDS IN FRUITS

FRUIT	CITRIC ACID
	percentage
Apples	
Crab	0.03
Delicious	None
Grimes Golden	None
Jonathan	None
McIntosh	None
Yellow Transparent	0.02
Cherry, Montmorency, canned	None
Currant, canned	1.92
Grapefruit	1.33
Lemon (juice)	6.08
Loganberry, canned	1.82
Orange, Florida	0.92
Pear, Bartlett, canned	0.42
Peach, Palora, canned	0.05
Pineapple	0.77
Plum, California	0.03
Damson	None
Quince	None
Raspberry, Black, canned	0.81
Red, canned	1.28
Strawberry, Everbearing	1.08
Tomato	0.47

Appendix E

SIMPLE STATISTICAL TREATMENT OF THE DATA OF NUTRITION INVESTIGATIONS

In quantitative scientific work, whether experimental or observational, it is important not only to bring the data of experiments or observations into comparable numerical form but also to measure, as definitely as may be, the validity of the mean results obtained.

In most modern laboratory courses in physics or in quantitative analysis, the student is taught to compute for a series of measurements or determinations some measure of the precision of the mean result. The *precision measure* thus taught in connection with physics and chemistry may or may not be exactly the same as the classical *probable error* which is so much used in the statistical analysis of observational data (as in economics, sociology, and public health work) and which is equally applicable to the results of laboratory experimentation.

Investigations in the chemistry of food and nutrition, especially since the use of laboratory animals in the study of food values and nutrition problems has become common, often deal with data which involve both the errors of measurement which apply to all laboratory work and also the physiological or individual variability of the experimental animals used—both precision of measurement in the ordinary laboratory sense and the elements of biometrics or of vital statistics as well.

As a matter of fact these two kinds of errors are not so distinct as the ordinary statement of them might seem to imply, the "errors" (variations) in a series of "purely physical" measurements being largely due to physiological variations such as those of eyesight and steadiness of hand in the measurer or measurers. Without elaboration of this consideration, however, it suffices for our present purpose to emphasize the fact that the particular form of precision measure known as probable error (P.E., E., or p. e.)

is applicable to the ascertainment of the degree of certainty or trustworthiness of the result of an investigation whose data are subject to either or both of these kinds of errors or variations. And the computation of the probable error yields incidentally a measure of the variability of the data which (expressed usually in the form of *standard deviation* or *coefficient of variation*) is often of added value in the interpretation of the results.

$$\frac{\text{Standard Deviation}}{\text{Mean}} \times 100 = \textit{Coefficient of Variation}$$

Jevons in his *Principles of Science* has given the following concise rules for the computation of probable error,* and definition of the value thus found:

Probable Error †

"The following are the rules for treating the mean result, so as thoroughly to ascertain its trustworthiness.

1. Draw the mean of all the observed results.
2. Find the deviations of each result from the mean.
3. Square each of these deviations.
4. Add together all these squares, which are of course all positive.
5. Divide by one less than the number of observations.‡ This gives the *square of the mean error*.
6. Take the square root of the last result; it is the *mean error of a single observation*. (Also called *Standard Deviation*.)

*The term probable error (like many other technical terms) may be regarded as more or less of a misnomer, and partly on this account some writers are inclined to criticize and minimize it. But the term is so well established that even ridicule seems hardly likely to displace it, and whatever the ambiguity of the *term* "probable error" the *conception* is one of very great importance which can and should be clearly understood by all students of science.

†Jevons' *Principles of Science*, page 387.

‡In the fifth of the numbered steps above quoted from Jevons, there is a difference of usage as to whether the division indicated therein shall be by the number of observations or one less than this number. (That is by a divisor which represents, (1) the number of objects observed, or (2) the number of intervals which one would have if these objects were set up in a row, "in array," for the purpose of observing the extent to which they differ.) This difference should never appreciably affect the conclusions drawn, for if there were one hundred observations the probable error would be affected to the extent of only one hundredth of its numerical value whereas the differences which one would be concerned to interpret would usually be relatively larger. The larger the number of observations the smaller the influence of this deviation of usage, and as the validity of this or any other precision measure is dependent upon the number of observations being large enough to ensure a "fair sample" of the data concerned, it is only when the number of observations is fairly large that it is worth while to compute the probable error. For full discussions of the gathering of data, the judgment of their adequacy for statistical treatment, and related problems see Chaddock's *Principles and Methods of Statistics*.

7. Divide now by the square root of the number of observations, and we get the *mean error of the mean result.* (Standard deviation *of the means.*)
8. Lastly multiply by the natural constant 0.6745 (or even by ⅔) and we arrive at the *probable error of the mean result.*

"The probable error is taken by mathematicians to mean the limits within which it is as likely as not that the truth will fall."

The advantage of computing the probable error rather than some other precision measure has been mentioned above. So far as concerns applicability to different types of data, one might equally well use the mean error omitting the final step in the calculation, which consists simply in multiplying this by a constant. The probable error has, however, the added convenience over the mean error (1) of being easily and simply defined in words as the limits within which it is as likely as not that the truth will fall; (2) of easy statement of the numerical likelihood of finding the truth within such wider limits as may be selected, and of the likelihood as to whether or not the difference between the means of two series of observations or measurements is a real or an accidental difference.

The probable error of the difference between two means is the square root of the sum of the squares of their respective probable errors. If the difference between two means were exactly the same as the probable error of this difference, then the chances would be exactly even as to whether the difference were a real or an accidental one; but if the difference were three times its probable error, then (assuming that the sampling was adequate and the data of such a nature as to make the rule applicable) the chances would be better than 20 to 1 that the observed difference was a real one and not attributable to accident or to individual variations.

A probable error is significant only in connection with the mean or the difference to which it applies.

Rietz and Mitchell* summarize as follows the rapidly increasing probability of the validity or reality of a finding or a difference according as the difference of two means is found to be equal to or several times greater than its probable error. They say:

"The exponential equation affords us a means of determining

*Rietz and Mitchell, *Journal of Biological Chemistry*, Vol. 8, page 305. This paper as a whole argues strongly for the general applicability of Gauss's Law of Error, and the rules derived from it, to the interpretation of the data of nutrition experiments. A relatively skeptical view is presented by Wilson, *Science*, Vol. 58, page 93 (August 10, 1923). Chaddock in his *Principles and Methods of Statistics* gives full and judicial discussions both of the uses and of the possible misuses and limitations of the ordinary statistical methods.

not only certain limits within which the probability is one half that a deviation will fall, *i.e.*, those set by the probable error, but also with what probability we may expect a deviation not to exceed *any* assigned limit. Thus, taking limits that are multiples of the probable error, Gauss's Law of Error enables us to assert that, for variates that follow this law, the chances that another random observation or the mean of any equal random sample will fall within the range ± E, ± 2E, etc., are as follows:

± E the chances are	even
± 2E the chances are	4.5 to 1
± 3E the chances are	21 to 1
± 4E the chances are	142 to 1
± 5E the chances are	1,310 to 1
± 6E the chances are	19,200 to 1
± 7E the chances are	420,000 to 1
8E the chances are	17,000,000 to 1
± 9E the chances are about	1,000,000,000 to 1

"It is improbable, therefore, that the deviation of another random observation will exceed the probable error many times."

Applicability. It is presumably not necessary to remind the reader that all these considerations apply only to "chance" or "compensating" errors and to normal individual variations; not to "constant" or "cumulative" errors or errors due to the use of incorrect methods or to biased or inadequate sampling. A more picturesque way of making the distinction is the statement that the Law of Error "applies only to errors and not to mistakes."

This distinction being kept clearly in mind, there still remains the question as to how closely one may expect the chance variations of any given kind of data to approximate the ideal of the perfectly symmetrical frequency distribution for which alone the above rules and ratios hold strictly and precisely true.

For critical discussions of this problem the reader may refer to the papers of Rietz and Mitchell and of Wilson and the textbook of Chaddock already cited as well as to many other books on statistical method written from various points of view.

Of special significance to the student of nutrition is the fact that variations which result from a multiplicity of causes, which plainly include the individual variations encountered in nutrition experiments, have quite regularly been found to approximate closely to the ideal distribution when studied on sufficient numbers of cases; from which it follows that the computation of probable error by the method above cited and its use as here indicated in the interpretation of findings and differences is in

full accord with our best scientific knowledge. But unless or until it be actually demonstrated that the particular data at hand do show a symmetrical frequency distribution, the computed probable error should be taken as an indication or approximation rather than as a precisely determined value to be stated dogmatically to several significant places of figures.

And always it is to be remembered that, in the interpretation of the data of nutrition research, statistical analysis is an important aid to, not a substitute for, good judgment.

Appendix F

THE PLANNING OF DIETS IN TERMS OF TWELVE FOOD GROUPS

Several government publications follow a plan of dietary discussion which divides all articles of food into a dozen groups as follows*: (1) milk and milk products; (2) potatoes and sweet-potatoes; (3) dry, mature beans, peas, and nuts; (4) tomatoes and citrus fruits; (5) leafy, green, and yellow vegetables; (6) other vegetables and fruits; (7) eggs; (8) lean meat, poultry, and fish; (9) flours and cereals; (10) butter; (11) other fats; (12) sugars.

A dietary can then be planned in terms of so much food from each of the twelve groups, and it is considered that entire freedom may be exercised (according to preference, price, etc.) in choosing within each food-group without seriously endangering the nutritional character of the whole.

Thus the Stiebeling and Clark recommendations for good low-cost food supplies for people of different ages and activities, tabulated in Table 29 herewith, are formulated in terms of these twelve food groups. This table could readily be made the basis for an estimate of the food needs of any family whose members are known, and the yearly figures reduced to any other time basis desired. Such a plan need not mean a monotonous diet; for many of the food groups are so broad as to provide for widely varied choices from time to time. Seasonal differences in the markets will often permit savings in cost at the same time that the desire for diversification of diet is being gratified.

As officially stated in the Yearbook,** its dietary recommendations (including those here reproduced as Table 29) "are not to be considered as ideal. Some nutritionists would undoubtedly go beyond them in certain respects. But the recommendations

*The particular wording and sequence here given is quoted from page 35 of the 1939 Yearbook of the U. S. Dept. of Agriculture.

**U. S. Dept. Agriculture Yearbook for 1939, "Food and Life," page 36.

are based not only on what is desirable, but on a painstaking study of existing American food habits . . . (and) take these habits into consideration instead of recommending what might be ideal but not in line with our habits." Keeping in mind this clear, official statement of the fact that the Federal recommendations do not fully represent the teaching of the newer knowledge of nutrition but are intentionally placed somewhere between the fully scientific position and the current habit which we seek to improve, one should not be disconcerted (rather one might well expect) to find one's own dietary practice or family food supply somewhat more fully representative of the modern views of nutrition than are the recommendations just cited.

For reference and comparisons with the data of Exercises suggested in this book or of dietary illustrations in its text, there is here reproduced the suggestion for "A Good Low-Cost Diet" as tabulated on page 338 of the 1939 Yearbook of the United States Department of Agriculture.

TABLE 29.—"A GOOD LOW-COST DIET"
(Yearbook, United States Department of Agriculture)

FAMILY MEMBERS	KINDS AND QUANTITIES OF FOODS FOR A YEAR											
Description	Milk, Quarts	Potatoes, Sweet-potatoes, Pounds	Tomatoes, Citrus Fruits, Pounds	Leafy, Green, Yellow Vegetables, Pounds	Mature, Dry Legumes, Nuts, Pounds	Other Vegetables, Fruits, Pounds	Eggs, Dozen	Lean Meat, Poultry, Fish, Pounds	Flour,* Cereals, Pounds	Butter, Pounds	Other Fats, Pounds	Sugars, Pounds
Children under 2 years	260	80	65	80	...	...	18	...	50	7	..	3
Children 2 to 3 years	365	90	65	130	...	40	22	15	80	10	..	7
Boys:												
4 to 6 years	365	100	65	130	7	75	22	25	100	15	..	15
7 to 8 years	260–365	120	65	180	10	100	22	65	140	20	3	25
9 to 10 years	260–365	130	65	200	10	140	18	80	160	20	20	40
11 to 12 years	260–365	140	65	200	15	140	18	90	180	20	20	40
13 to 15 years	260–365	160	65	160	15	175	18	100	230	20	30	50
16 to 19 years	260–365	220	65	160	15	175	13	140	310	20	40	65
Girls:												
4 to 7 years	365	100	65	130	7	75	22	25	100	15	..	15
8 to 10 years	260–365	120	65	180	10	100	22	65	140	20	3	25
11 to 13 years	260–365	130	65	200	10	140	18	80	160	20	20	40
14 to 19 years	260–365	140	65	200	15	140	18	90	180	20	20	40

TABLE 29.—"A GOOD LOW-COST DIET"—*Continued*
(Yearbook, United States Department of Agriculture)

FAMILY MEMBERS	KINDS AND QUANTITIES OF FOODS FOR A YEAR											
Description	Milk, Quarts	Potatoes, Sweet-potatoes, Pounds	Tomatoes, Citrus Fruits, Pounds	Leafy, Green, Yellow Vegetables, Pounds	Mature, Dry Legumes, Nuts, Pounds	Other Vegetables, Fruits, Pounds	Eggs, Dozen	Lean Meat, Poultry, Fish, Pounds	Flour,* Cereals, Pounds	Butter, Pounds	Other Fats, Pounds	Sugars, Pounds
Men 20 years & over:												
Very active	180	300	65	160	25	175	13	160	420	20	60	80
Moderately active	180	160	65	160	20	175	13	130	230	20	30	65
Sedentary	260	140	65	180	10	140	18	90	160	20	20	40
Women 20 years & over.												
Very active	180	160	65	180	15	175	18	100	230	20	30	65
Moderately active	180	140	65	180	15	165	18	90	180	20	20	50
Sedentary	260	100	65	180	10	140	18	90	120	20	20	40
In pregnancy	365	140	65	250	10	200	22	90	170	20	20	40
In lactation	365	170	65	250	10	200	22	100	210	20	30	50

*Bread is counted as equivalent to two-thirds its weight of flour.

Appendix G

GLOSSARY*

acidosis: any condition in which the body's alkaline reserve is depleted; may result from abnormal loss of alkaline salts from the body or (more commonly) from abnormal accumulation of acids. Term often used in restricted sense as synonymous with ketosis, defined below.

acrodynia: a disease of the skin.

adipose: fatty.

adrenal (suprarenal) glands: a pair of endocrine glands, one being situated above each kidney.

adrenaline (epinephrine): a hormone secreted by the adrenal glands.

alanine: one of the digestion products of proteins.

alkaline reserve: the amount of potentially alkaline material available in the body to neutralize acids. Term often used in restricted sense as synonymous with the bicarbonate of the blood.

allergy: a condition of unusual or exaggerated specific susceptibility to a substance which is harmless in similar amounts for most individuals.

anorexia: lack or loss of appetite for food.

appetite: the inclination or desire to eat; distinguished from hunger as the drive to eat.

arginine: one of the digestion products of proteins.

aspartic acid: one of the digestion products of proteins.

atrophy: a wasting in size.

base: a substance which combines with acids to form salts.

bile: fluid secreted by the liver and poured into the intestine.

buffer: a substance which tends to prevent or minimize a change in the reaction of a solution.

*Students please note that the Index should also be consulted.

calciferol: vitamin D_2; a form of antirachitic vitamin produced by irradiation of ergosterol.

calcification: the process by which tissue becomes hardened by a deposit of calcium salts within its substance.

calorimeter: an instrument for measuring the heat change in any system; such as the bomb calorimeter which is used to determine the energy value of foods through measurement of the heat liberated during their oxidation; and the types of apparatus illustrated and discussed in Chapter IV by which is measured the heat production of the body.

carotenes: yellow pigments having the formula $C_{40}H_{56}$ of which three modifications are known, alpha-, beta-, and gamma-carotene, respectively, each serving nutritionally as a precursor of vitamin A.

casein: the principal protein of milk.

cephalin: a constituent of the brain; a substituted fat which contains phosphorus and nitrogen.

cerebrosides (galactolipids): constituents of brain and nerve substance which contain nitrogenous, fatty, and carbohydrate radicles.

chlorophyll: the green pigment of plants.

cholesterol: the principal sterol of animal origin.

chyme: the partially digested material which the stomach passes on into the intestine.

conjunctivitis: inflammation of the membranes which line the eyelids and cover the eyeball.

connective tissue: a tissue holding together and in place other, usually more active, tissues, as, for example, muscle fibers or the cells of glands.

constitution: an important but not well defined concept, perhaps usually understood as meaning that inherited potentiality of health which one can impair but cannot enhance. Recent work in nutrition is enabling us to take a less fatalistic and more constructively scientific attitude toward the individual health-potentiality which is partly an inheritance and partly the result of nutritional conditioning both before and after birth.

cysteine: the reduction product of cystine, which very readily becomes reoxidized to cystine.

cystine: one of the digestion products of proteins.

deaminization: the process by which the amino group, $-NH_2$, is split out of a molecule, as deaminization of amino acids in metabolism.

dermatitis: inflammation of the skin.

electrolyte: a substance which in aqueous solution breaks down into electrically charged particles known as ions.

endocrine: secreting internally or into the blood stream; as endocrine glands, or glands of internal secretion.

environment: while usually suggesting surroundings, includes, by scientific definition, nutrition and any or all other *environmental factors*, that is, everything that conditions the life-process except the hereditary or genetic factors. See also Internal environment.

enzyme: consult the Index for explanation in the text.

epinephrine (adrenaline): a hormone secreted by the adrenal glands.

ergosterol: a sterol found abundantly in fungi such as ergot and yeast and in very small amounts among the sterols of higher plants; on exposure to ultraviolet light of suitable wavelength it is converted into vitamin D_2.

flavin: yellow-green fluorescent water-soluble pigment. The flavin of greatest interest in nutrition is riboflavin (vitamin G, lactoflavin, lactochrome).

glutamic (glutaminic) acid: one of the digestion products of proteins.

glutathione: a substance containing glutamic acid, cysteine, and glycine which is found in active plant and animal tissues and is believed to play an important part in the oxidation and reduction reactions of the cells.

glycine (glycocoll): one of the digestion products of proteins.

hemeralopia: night blindness; condition in which a person sees more poorly at night or in a dim light than his normal vision would seem to warrant.

hemoglobin: the red protein found in the red blood cells; contains iron and is capable of uniting loosely with oxygen.

hemorrhage: (1) a loss of blood; (2) any portion of blood which has escaped the blood vessels.

histidine: one of the digestion products of proteins.

hormone: consult the Index for explanation in the text.

hydroxyglutamic acid: one of the digestion products of proteins.

hydroxyproline: one of the digestion products of proteins.

insulin: the active substance of the internal secretion of the pancreas.

intercellular: between the cells.

internal environment: the resultant-condition within the living body of all factors other than those which are directly hereditary. While most that has hitherto been written regarding the internal environment emphasizes its relative constancy, we are now learning that it is very importantly influenced by nutrition.

in vitro: (literally "in glass") in a test-tube or other laboratory apparatus as contrasted with

in vivo: in the living organism.

ion: electrically charged atom or group of atoms such as is formed when an electrolyte is dissolved in water.

irritability: the ability to respond to a stimulus.

isoleucine: one of the digestion products of proteins.

isomers: chemically different substances having the same empirical formula.

keratin: a very insoluble protein which forms the base of epidermis, hair, and of all horny tissues.

keratomalacia: softening of the cornea.

ketosis: a condition in which, due to the failure of the body to complete the oxidation of fatty acids, there is an abnormal accumulation of socalled "ketone bodies" (acetone, hydroxybutyric acid, and acetoacetic acid).

lecithin: a substance having the molecular structure of a fat in which one of the fatty acid radicles is replaced by phosphoric acid carrying choline (a nitrogenous base).

leucine: one of the digestion products of proteins.

longevity: length of life.

lysine: one of the digestion products of proteins.

matrix: the intercellular portion of a tissue.

methionine: one of the digestion products of proteins.

neutrality: the state of being neither acid nor alkaline.

norleucine: one of the digestion products of proteins.

organic: containing the element carbon; however, carbon dioxide, carbonic acid, and the carbonates and bicarbonates are not ordinarily regarded as organic.

"original chromosomal endowment": the set of chromosomes with which the individual is endowed at conception.

osmotic pressure: a physico-chemical property shown by substances in solution. It is most clearly manifest in the phenomenon of osmosis, which occurs when the solution is separated from pure water (or from a solution containing less of the dissolved substance) by a socalled semipermeable membrane, through which can pass water but not the substances in solution. Under these conditions, water passes through the membrane into the (more concentrated) solution.

oxidation: a chemical process involving the addition of the element oxygen to a compound, or the removal of the element hydrogen from the compound, or a chemically analogous change.

oxidation potential: a measure of the property of inducing oxidative changes.

petechiae: tiny hemorrhage-spots, as in the skin.

phenylalanine: one of the digestion products of proteins.

phosphate: salt of phosphoric acid H_3PO_4. Salts of the type BH_2PO_4 in which only one hydrogen has been replaced by reaction with base are called *mono-* or *primary* or *acid* phosphates; salts of the type B_2HPO_4 are called *di-* or *secondary* or *basic*.

phospholipids (phospholipins, phosphatids): substituted fats containing nitrogen and phosphorus.

precursor: a substance which is converted into another. For example, the carotenes are precursors of vitamin A, as explained in the text.

proline: one of the digestion products of proteins.

prothrombin: a precursor of blood-clot.

protoplasm: the essential substance of both the cell body and nucleus of cells of animals and plants, regarded as the only form of matter in which the phenomena of life are manifested.

provitamin: a substance which may be converted into a vitamin; thus, the carotenes are provitamins A, ergosterol is a provitamin D.

radicle: a characteristic constituent part of a substance; as the amino-acid radicles in proteins.

reduction: a chemical process involving the addition of the element hydrogen to a compound, or the removal of the element oxygen from the compound, or a chemically analogous change.

rennin: the milk-curdling enzyme of the gastric juice.

ribose: a simple sugar containing five carbon atoms.

salt: the product of the reaction of an acid with a base.

senility: the state of showing the characteristics of old age.

serine: one of the digestion products of proteins.

sterols: a chemically related group of fat-soluble substances of very complex molecular structure; the provitamins D are important members of this group of substances.

tetany: a disease characterized by sudden, violent, involuntary contraction of the muscles of the extremities.

threonine: one of the digestion products of proteins.

tonus (tone): a sustained state of partial activity such as exists in muscles at all times.

Trichinae: nematode parasites, one of which, *T. spiralis*, is frequently found in a cyst in hog muscle. Human beings also may become infested with these parasites (the resulting disease being known as trichinosis) by eating undercooked pork from hogs so affected.

tryptophane: one of the digestion products of proteins.

tyrosine: one of the digestion products of proteins.

ultraviolet rays: rays of light of slightly shorter wave-length than visible light.

urea: the principal nitrogenous end-product of the metabolism of proteins in the body.

valine: one of the digestion products of proteins.

xerophthalmia: a dry and lustreless condition of the eyeball.

SUBJECT INDEX